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THE DEPARTMENT OF AGRICULTURE

OF

PORTO RICO

YELLOW-STRIPE DISEASE INVESTIGATIONS
(PROGRESS REPORT)

VOL. III, No. 4—OCTOBER, 1919

PUBLISHED BY
THE INSULAR EXPERIMENT STATION
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THE YEAR'S EXPERIENCE WITH SUGAR-CANE MOSAIC OR YELLOW STRIPE DISEASE.

By F. S. EARLE.

In the JOURNAL OF THE DEPARTMENT OF AGRICULTURE AND LABOR for July 1919 (not published till January, 1920), Mr. J. A. Stevenson has given a summary of his studies on this disease, (for which he has proposed the name "Mottling"), made up to the time of his departure from Porto Rico in October, 1918. Active work has been in progress since that time on various lines connected with this investigation and it seems desirable at this time to make this report of further progress.

The present writer came to Porto Rico in August, 1918, commissioned by the United States Department of Agriculture to investigate this disease and with instructions to coöperate as fully as possible with both the Federal and Insular Experiment Stations and any other agencies or individuals engaged in any phase of its study. After a preliminary inspection of the situation it seemed best to divide the problem into a number of projects in which the different workers could interest themselves, thus avoiding duplication of effort and also centering attention at first on those phases of the problem that seemed to promise the most immediate practical results. The following projects or divisions of the general problem were outlined and the effort was made to get work started in each of them: 1st. A field survey to determine the present extension of the disease. 2nd. Methods of eradication adapted to recent outbreaks or cases of partial infection. 3rd. Methods of cultivation best adapted to badly diseased fields. 4th. Statistics of sugar production as affected by the

disease. 5th. Methods of natural or artificial infection. 6th. Resistance and immunity—variety studies. 7th. An ecological survey of the insect inhabitants of the cane fields with special search for possible carriers of the disease. 8th. Cage experiments with insects suspected as disease carriers. 9th. Morphological, histological and cytological studies of diseased cane. 10th. Studies on the nature of the disease and search for a causal organism. 11th. Chemical studies of diseased as compared with healthy cane. 12th. Soil studies: Effects on the disease of different soils, soil sterilization, special fertilizers or other topical applications. 13th. Relationship with other similar diseases: A comparative study of the mosaic diseases.

In the following pages these topics will be taken up in order and the results so far obtained discussed.

1st. Field Survey—Present Distribution of the Disease.

The disease has now (November, 1919), been found in nearly all parts of Porto Rico.[1] The Yabucoa valley is the only well-marked region of the Island where at least occasional cases have not been found. This, however, does not necessarily indicate the rapid invasion of new territory. Several of the recently located outbreaks in eastern Porto Rico give clear evidence that the disease had been present for at least two or three years. The rapid spread of the disease from one part of the Island to another that is indicated by the various published reports concerning it will have to be accepted with some caution for it is evident that it has often been present in the fields for long periods without attracting attention. On the other hand certain regions, especially along the south coast, which were carefully inspected two years ago and found free from it are now quite heavily infected. For some unknown reason infection seems to have been much more active on the south west than on the north-east part of the Island.

While the disease thus occurs in practically all parts of the Island its distribution is by no means uniform. Along the north coast from Bayamón to Barceloneta it occurs on every plantation and practically in every cane field, but as yet infection is only partial, running from 1 or 2 per cent up to 50 or 60 per cent, and even considerably higher than this in some of the upland fields among the limestone hills. The fact so often noted by Stevenson still holds that the disease is much

[1] A few cases have also been found in the Island of Vieques.

more abundant in these upland valleys than in the level lands near the sea. While the disease is now a commercial factor of importance in this district having caused very considerable losses in sugar yields during the past two years, there is still an abundance of healthy seed cane available, and as shown by the years experience at Central Carmen and Plazuela (see Bulletin 22) it is perfectly possible to control it at reasonable expense.

Farther west from Arecibo to Central Coloso below Aguadilla conditions are more serious. As shown by Mr. Figueroa's article on another page of this publication, yields of sugar have fallen off about 50 per cent in this district during the past three years. Even here, however, infection is not complete. With care good seed can still be selected from certain fields, and as shown by experience at Central Coloso (see Bull. 22) the disease can be controlled by methods of eradication if faithfully carried out. Cane planting has, however, been abandoned on large areas in this district, especially among the hills, as a consequence of the losses caused by this disease.

From Rincón around the west coast to San Germán infection is almost complete. Many fields are actually 100 per cent infected, the great majority are over 90 per cent diseased, and it is doubtful if any field can be found with as little as 50 per cent of sick cane. Much of the cane from this district goes to the big central at Guánica on the south coast, so that the published statistics do not fully show the facts in regard to sugar losses, but there can be no question that they have exceeded an average of 50 per cent. Most unfortunately, almost no healthy seed cane is available in this district. This will cause a still further falling off in the near future. The possibility of establishing seedbeds of healthy cane in this district has been discussed in another publication (Bulletin 22, pp. 15–16), where the opinion was expressed that though difficult this was not impossible. The suggestion was also made that for this district the planting of the resistant kinds discussed in Bulletin 19 might prove a more practical measure than attempts at eradication.

From San Germán eastward to Peñuelas the disease is also very prevalent. It has been spreading more rapidly during the past year in this district than in any other part of the Island, but there are still localities that have largely escaped so that some healthy seed cane is still available. The coast district near Guayanilla is as yet but little infected.

North of Ponce and in the neighborhood of Juana Díaz some

fields are badly diseased, but for the remainder of the south coast infection is still local and scattering and the disease can as yet hardly be said to have had any commercial effect.

The same may be said of the east coast and of the north coast east of Bayamón though severe local outbreaks occur at Trujillo Alto and in certain fields near Carolina.

Comparatively little cane is grown in the interior of the Island, but what there is is heavily infected as far east as Cayey. Outbreaks of importance also occur at Caguas and Juncos.

2nd. Methods of Eradication.

On arriving in Porto Rico last year scattered outbreaks of the disease were being reported in the eastern part of the Island in what was supposed to be clean territory. It seems obvious that such diseased plants should be at once destroyed to prevent further contagion without waiting for a more detailed study of the disease, and this advice was always given. In many cases it proved to be impossible to impress owners and managers with the gravity of the situation, but others responded immediately and did most effective work in cleaning up and dominating the disease. Secondary infection, the spread of the disease from infected to healthy plants, was often so active that at first it was feared that this method would not be effective in regions where infection was at all general, and it was only advised for isolated outbreaks. This method of controlling the disease was first suggested in print by Stevenson in the Spring of 1918 (Revista de Agricultura 1: 23, May, 1918). It had, however, been previously successfully practiced by Mr. Enrique Landrón, a cane grower in the hills back of Arecibo in a district where the disease was very active and destructive. It was also being followed with good results by Mr. José R. Aponte in the low lands of Arecibo near the Central Cambalache. Some eradication work had been done on the grounds of the Insular Station at Río Piedras, and Central Fajardo was carrying out a comprehensive eradication campaign. A study of these operations and continued field observations in all parts of the Island soon caused a change of view, and in November, 1918, Circular No. 14 was published strenuously advocating this method for controlling the disease in all parts of the Island, or at least in any region where healthy seed cane could still be secured. An active propaganda was undertaken among the cane planters in favor of this method and a considerable number of them

were induced to give it a trial on a large scale. The results obtained from this work during the first season have recently been gathered together and published as Bulletin No. 22 of the Insular Experiment Station, to which the reader is referred for fuller details. Only the summary need be quoted here which states: "1st. it is considered proven that the cane mosaic or yellow stripe disease can be controlled by the method of eradication discussed in Circular No. 14, in all regions where a supply of healthy seed can still be obtained; 2nd. in regions of complete infection the establishment of healthy seed fields is necessary before a campaign of eradication can be undertaken. This is difficult but not impossible. Failure at one time may be followed by success at another under apparently identical conditions." The method of eradication referred to in the above publications consists in, 1st, planting healthy seed that has been carefully selected while the leaves are still attached. Attempts at selection after the leaves are cut are useless. 2nd, in the frequent inspection of the fields while the cane is young to pull out such cases of disease as may occur either from overlooked diseased seed pieces or from secondary infection. Of the two operations the second is really the more important, for if some bad seed is planted it is quickly detected and removed by these inspections, but the best of seed planted in an infected district and not carefully inspected and "rogued" will inevitably become contaminated through secondary infection. Inspection should begin when the young cane has made its third leaf and should be repeated two or three times a month until the cane closes. It is useless to attempt eradication in large cane except in the case of fields which are to be cut for seed. If large cane becomes infected it is usually best to wait until after it is cut and then clean up the young ratoons which should be treated exactly like plant cane. It is necessary to dig out and replant the whole stool if any of the stalks show the disease.

While it is comparatively easy and inexpensive to reduce the percentage of disease by this method to a point where it ceases to be a commercial factor, it must be admitted that complete eradication is very difficult. It is altogether probable that seed selection and the inspection of young fields will have to be continued as part of the accepted routine of cane growing. Fields will have to be protected from this disease just as they are now protected from weeds and grasses. It is not to be expected that this disease will ever be banished from Puerto Rico.

3RD. METHODS OF CULTURE BEST ADAPTED TO BADLY DISEASED FIELDS.

The unexpectedly favorable results from eradication, and the finding of immune and resistant kinds (see Bulletin 19) have greatly reduced the supposed importance of this topic. It is obviously unwise to continue cultivating diseased fields of the ordinary varieties with certain loss of from 20 to 50 per cent of yield when such loss can be cheaply avoided by the methods of eradication or by the substitution of immune or resistant kinds. The fact remains, however, that in many districts the fields are now heavily diseased, and even if the above facts were universally accepted and acted upon, which, unfortunately is far from being the case, it would still take some years before the present conditions could be radically altered. Meanwhile what sugar is made will have to come from heavily diseased fields so, during this transition period at least, the best method of treating them becomes a question of great and immediate importance. It is indeed fortunate that this crisis in the sugar industry of western Porto Rico comes at a time of such phenomenally high prices. Otherwise losses would inevitably be very severe. Now even half the normal yield of sugar may show a profit or at least avoid a disastrous loss. Circular No. 17 (issued in Spanish) entitled "Recomendaciones sobre el Cultivo de la Caña en Puerto Rico." was largely written as a contribution to this problem. It was, however, a study of the cultivation problem in general and its underlying idea was to show that by using improved agricultural methods cane can be grown not only at a less cost per acre but with the greater yields secured at a still greater saving in the cost per ton. With the continued rise in the price of sugar the immediate problem with diseased fields is not so much how to reduce costs as how to increase yields even at the expense of a reasonable increase in cost. Luckily, enough data is at hand to show that cane even when fully attacked by the mosaic will respond to increased applications of fertilizers, especially the nitrogenous fertilizers. Under present conditions, therefore, cane growers in heavily infected districts should largely increase their application of fertilizers. Instead of using 2 bags per acre, which at present is a common practice, they should use 4 bags, and on top of this a bag of sulfate of ammonia, or in the dry season nitrate of soda. As an example of yields that have been obtained from heavily diseased cane an instance can be cited on the irrigated lands of the south coast when a 20 acre field of *gran cul-*

tura (long-season plant cane) of the susceptible B–3922 variety gave 51 tons per acre last year though it was estimated as 90 per cent diseased. The same field in previous years before the disease appeared and under the same cultivation had given an average of 65 tons. Fields of 4- and 5-year Rayada ratoons on the north coast which were from 90 to 95 per cent diseased, when well cultivated and fertilized as above, gave last year as high as 20 and 25 tons of cane per acre though the year before with ordinary care and fertilizing they had only given 5 to 10 tons per acre. This shows that much can be done to increase yeilds even in heavily diseased fields by better cultivation (by which is meant stirring the land with implements, not mere surface hoeing) and by the heavily increased use of nitrogenous fertilizers. Under existing conditions these methods are certainly justified. The pressing problem of the moment is to provide a sufficient supply of cane to keep the mills of western Porto Rico grinding for the next two or three years, for it will take that length of time to dominate the disease situation there by the best of efforts either in eradication or the planting of resistant kinds.

4TH. STATISTICS OF SUGAR PRODUCTION AS AFFECTED BY THE DISEASE.

On another page of this publication Mr. C. A. Figueroa, inspector of agriculture with the Insular Department of Agriculture, gives interesting statistics showing the tons of sugar produced at each of the mills on the Island during the past three crops and the corresponding number of acres of cane harvested. The losses in sugar in the different zones in which he divides the Island agrees so closely with the percentage of disease present as to leave no doubt that this has been the determining factor. It is unfortunate that rainfall tables were not available in sufficient detail so that they might have been included also, this being the only important factor in crop production that is omitted. The severe drouth of the Summer of 1918 unquestionably reduced sugar yields. Field notes show that in August and September cane was suffering badly for want of rain in all parts of the Island, excepting in the Río Piedras-Loíza district on the northeast and the Mayagüez district at the west. In both of these districts local showers prevented serious damage. In the first of these districts (corresponding to zone 9 of the tables), where the disease only exists in a few scattered localities, the crop of 1919 was larger than that of 1917 and only slightly smaller than that of 1918. In the fully diseased Mayagüez district the loss was 32.4 per cent in 1918 and 39.4 per cent in 1919. The south coast district

(zone 5) lost 10.8 per cent. This was all chargeable to the drouth and to unseasonable rains during the crop which lowered sucrose and purity. The Arecibo district (zone 2) on the north coast suffered about equally from drouth, but here where the disease was abundant the loss reached 39.7 per cent. In the Arecibo district proper with the Aguadilla district omitted, where rainfall was more abundant, the loss reaches nearly 50 per cent. The difference between the losses from these two regions can only be chargeable to the mosaic disease. We are safe in concluding in a general way that when infection reaches an average of 60 to 80 per cent losses of sugar will be from 30 to 40 per cent.

5TH. METHODS OF NATURAL OR ARTIFICIAL INFECTION.

One of the most remarkable things in the history of this disease is the fact that so many investigators in different parts of the world have studied it for years without suspecting its infectious nature. It has been known in Java since 1892, but as late as 1910 in the comprehensive paper by Wilbrink and Ledebour (Archief V. de Java Suikerindustrie 18: 464–518) it is considered as an abnormal bud variation. No literature is at hand which shows any change in this view on the part of the Java pathologists. This view was at first accepted also by Mr. S. L. Lyon in the Hawaiian Islands, though he seems to have been the first to suspect its real nature for he soon characterized it as "an infectious chlorosis." Stevenson took up the study of the disease independently in Porto Rico in 1915 without suspecting its identity with the "Gele Strepenziekte" of Java. In fact, in his latest paper (JOURNAL DEPARTMENT OF AGRICULTURE OF PORTO RICO 4:3, July 1919,) he does not accept this identity as proven. In his earlier papers he confused the symptoms of the yellow stripe disease with those of root disease. Later he clearly recognized that he was dealing with a distinct specific malady, but he explained it as caused by degeneration or abnormal variation. It was not till the spring of 1918 (REVISTA DE AGRICULTURA DE PUERTO RICO 1: 18, May, 1918,) that he came to recognize it as an infection.

Secondary Infection.

It has from the first been recognized by all workers with this disease that it was "hereditary," that cuttings from diseased stalks quite uniformly produced diseased plants. The rapid spread of the disease in Porto Rico indicated clearly that there must also be a

secondary infection by which the disease was communicated from diseased to healthy plants. In fact, a careful reading of the records of field experiments in the Java literature shows that this secondary infection was also present there, though for some reason it was not recognized. On arriving in Porto Rico careful attention was given to this phase of the subject and, as will be seen by the following extracts from field notes, it was not difficult to abundantly demonstrate its occurrence and its importance in spreading the disease.

Extracts from Field Notes on Secondary Infection.

"Los Caños, September 9, 1918.—A field of spring-planted Yellow Caledonia is very interesting. Evidently a few pieces of diseased seed were planted. The stools springing from these are much dwarfed and the leaves are all clearly infested from the ground up. In every case these stools were clearly foci of infection, as they were surrounded by a number of more recent cases in which the top leaves were infected while the bottom ones were healthy and where the growth of the plant was but little or not at all checked. In these secondary cases often only one stalk in a stool was affected."

This was the first case in which secondary infection was clearly differentiated from primary or seed infection. The effects of the disease on the Yellow Caledonia are very strongly marked and there could be no doubt as to the correct interpretation of the facts. The same conditions have since been observed in literally hundreds of fields in all parts of the Island.

"October 19, 1918.—The above field has gone from bad to worse. There are now many more cases than were observed last month. It is doubtful if over 5 per cent of the seed was infected but fully 30 per cent of the stools are now diseased."

"Los Caños, October 31, 1918.—The attempt was made to clean up part of a small triangular field of Yellow Caledonia plant cane near the mill in order to try some inoculation experiments. The cane was about 2 feet high. A little over 11 per cent of the seed was found to be diseased and was pulled up. About six weeks later (12–16–1918) 27 per cent of the stools were found to be diseased in the part of the field from which the diseased seed had been removed, while in the remainder of the field 67 per cent of the stools were diseased, the one "roguing" seeming to have reduced the number of cases by 40 per cent. These figures serve to show how rapidly the disease was spreading by secondary infection at this time."

"Los Caños, August 23, 1919.—A field of March-planted cane from carefully selected seed which came up healthy and remained so for some time now shows numerous infections on the side next a diseased ratoon field. Most of these cases are recent, the cane leaves being entirely normal up to six feet or more. This illustrates the fact that large cane may become diseased. It also shows that secondary infection has been much more active during the past two months than it was earlier in the season when the cane remained comparatively healthy though equally exposed to the disease."

"Central Cambalache, September 7, 1918.—A count in a certain field of *gran cultura* cane near the pump house showed 6 per cent infection. The cane was then about one foot high."

"December 16, 1918.—A count at the same spot showed 50 per cent of infection."

"Central Cambalache, August 22, 1919.—Numerous cases of recent secondary infection were observed in large cane six and 8 feet high."

"Central Coloso, January 2, 1919.—All fields in this district that are planted without seed selection are heavily infected with mosaic, mostly running from 75 per cent to 100 per cent diseased. For the past two years this *central* has been paying attention to seed selection. Fields planted with selected seed are showing an average of only 25 per cent to 30 per cent of disease. On one-half of a large field of *gran cultura* planted with selected seed they have tried pulling up diseased cane. It has now been gone over three times. At the first pulling 12 per cent of disease was found and removed. At the third pulling only 3 per cent of disease was found. The cost of such pulling was 45 cents to 50 cents per acre. At this time this part of the field is practically clean; almost no disease can be found. The other half of the field from which no diseased cane was pulled now shows fully 30 per cent disease."

"August 2, 1919.—Another inspection showed but little change in the above situation."

"Yauco, January 28, 1919.—Examined a field of young cane next to town which is now about three feet high. Secondary infection has evidently been very active. Judging from the present condition of diseased stools. less than 15 per cent of the seed was infected. Now 85 per cent of the stools are infected and many of the cases are evidently very recent."

"Yauco, April 10, 1919.—A field was observed here some time ago that had been planted by 'breaking banks' in a recently cut cane field but without destroying all of the old stubble. At the time of this first observation the seed cane had all germinated and was apparently all healthy. Considerable disease was, however, showing on ratoons from the old stubble between the rows. At this date many of the diseased ratoons are still growing and the plant cane now shows from 15 per cent to 20 per cent of disease clearly caused by secondary infection."

"Santa Rita, Guánica, December 31, 1918.—Mr. Bourne, who is in charge of experimental work here, has shown me a field of young B–3312 cane from which he pulled up 6 per cent of diseased plants a month ago. According to his count it now has 11 per cent of disease while an adjoining field of this kind planted at the same time from the same seed but from which no disease cane has been pulled now shows 25 per cent of disease. The 11 per cent in the one case and the 19 per cent in the other evidently represented secondary infections."

The immunity experiment conducted at Santa Rita, Guánica, which has been fully reported in Insular Experiment Station Bulletin 19, gave one of the most convincing proofs of secondary infection. Thirty healthy seeds of each of 90 varieties were planted in early October, 1918. Every third row was planted with diseased

Rayada so that each kind was uniformly and completely exposed to infection. By December 31st all of these kinds excepting the immune Kavangire had developed from 50 to 100 per cent of disease. No more conclusive proof of infection than this could be possible.

The Means by Which Infection is Carried from One Cane to Another.

While nothing can be more certain than that this is an infectious disease, that the contagion is carried from sick plants to healthy ones, we so far knew nothing as to the means by which this is accomplished. On reading Stevenson's article on this disease published in *Phytopathology* (7:418–425, 1917), the idea at once occurred to the present writer that an insect carrier was involved, as is the case with some of the other mosaic diseases and with the Curley Top of the beet. A letter was written to Mr. Stevenson making the suggestion and asking if he had any field observations that would support it. Since coming to Porto Rico this question has been constantly in mind as it is of great practical importance. At times field observations have been made that seem to strongly support this hypothesis. For instance, at the Santa Rita immunity experiment when the disease was running so rapidly in December there was an unusual abundance of leaf hoppers of several species. They literally rose in swarms when walking through the young cane. Later when the disease had become so much less active the leaf hoppers had practically disappeared. Very few of them could be found. The aid of the entomologists was early invoked for help in the solution of this problem. Extensive cage experiments were tried with a considerable number of cane insects both here and at the Federal Station at Mayagüez. Professor Smyth gives an account of his work here in another part of this publication. The Mayagüez experiments will be reported in the Annual Report of that Station. Only 4 takes were secured by Professor Smyth out of 185 experiments. Under other conditions this might be accepted as proof that insects do sometimes carry the disease, but as the chance for accidental infection is always present in Porto Rico so small a percentage of takes can not be considered as conclusive. Professor Tower of the Federal Station reports no takes at all as the result of his experiments. The case therefore still stands as not proven.

The belief, however, remains that insect carriers of some kind are responsible for the spread of the disease. This would completely account for all of the observed facts and no other suggestion has been made that can do so.

To What Distance can the Contagion be Carried in Cases of Secondary Infection?

In the field at Los Caños, where secondary infection was first clearly observed, the secondary cases were all clustered quite closely about the primary cases of seed-infected stools. In fact, most of them were in immediately adjoining stools. This seems to be the normal method of spreading, from an infected hill to those nearest to it. Instances have frequently been noted where a roadway or an irrigation ditch has acted as a fairly efficient but never as a complete barrier. Just east of the town of Bayamón there is a strip of pasture land with no cane fields for a width of perhaps half a mile. This has served as a barrier and has for three years prevented the disease from passing eastward.

On the other hand the disease is constantly appearing in new districts and at times under circumstances that make it highly improbable that diseased seed cane had been introduced. Of course in most cases new outbreaks are easily traced to diseased seed. At Central Fajardo at least two instances have been noted where a few isolated cases have been discovered in fields far removed from any other diseased cane and where no contaminated seed could possibly be traced. At Central Aguirre, too, a number of such scattered diseased stools have been found at points far distant from any known source of infection. As an instance, four diseased stools were found near together in the middle of a field near the mill. At that time no other diseased cane had been found within a number of miles of this place. A careful search of the field from which this seed cane came failed to show any sign of disease. While secondary infection thus usually takes place between diseased canes and those immediately adjoining it seems clear that at times the infection may be carried for very considerable distances.

Periodicity or Irregularity of Secondary Infection in the Same Locality.

It is a matter of common observation that at some times this disease spreads much faster that at others. Popular opinion seems to be that the spread is fastest in late summer and fall and less active in the spring. Such observations as have been recorded tend to confirm this view, but it is by no means proven that there is any such periodicity in the irregularity of infection. The point needs further study since it might have an important bearing on the time for attempting to establish seed fields in infected territory.

In August it was noted at both Cambalache and Los Caños near Arecibo that secondary infection had recently become quite active

in spring-planted fields that had largely escaped contagion earlier in the season.

The most remarkable instances of irregularity in the spread of the contagion is that recorded in Insular Experiment Station Bulletin 19 on the immunity experiment at Santa Rita. Healthy seed planted in early October was quite fully infected by the end of December, showing unprecedented activity in infection. That planted early in December never became over half infected, nine of the varieties escaping entirely, while that planted the last of December had in April only developed 6 and 8 per cent of disease. It must be remarked that this last was not interplanted with diseased cane like the others, but on the side adjoining diseased old cane it had only developed 8 per cent of disease, showing a most remarkable falling off in virulency from the condition in the same field in November and December.

Difference in the Activity of Secondary Infection in Different Localities.

Since this disease first attracted attention in Porto Rico a marked difference has been noted in its behavior in different localities. Stevenson in his various reports has frequently called attention to the fact that it always seems to spread faster among the hills of the interior than in the open level lands near the sea. That this condition still prevails has been confirmed by hundreds of observations made during the past year. At least for the whole extent of the north coast it is rare to find a field near the sea that is heavily infected, but back in the valleys among the limestone hills it is equally rare to find one that is not so infected. Even when the seed infection has been about the same the disease has spread much more rapidly among the hills. This is not so marked on the west coast, where practically all of the fields are now heavily infected.

In a general way the spread of the disease by secondary infection has been much more rapid and alarming in the territory west of a line drawn from Arecibo or Barceloneta to Ponce than it has been at any point east of that line. No cases have been observed in eastern Porto Rico where entire fields have been quickly involved, as happened at the Santa Rita immunity experiment and in the attempted seed field plantings at Los Caños and Florida. Secondary infection has occurred in all districts, but in the eastern part it has involved comparatively few plants at any one time.

It is a curious fact that in the propagating house at the Insular Experiment Station no secondary cases were observed for many

months, although healthy and diseased plants were growing side by side for three years. It is only during the last six months that a few such cases have appeared. In some cases diseased and healthy cuttings were planted in the same pot and grew with their roots and leaves intermingled for over a year with no transmission of the disease taking place. Again, diseased and healthy plants have been grown in the same wire netting cage in the open grounds with no development of secondary cases even when the cage was heavily colonized by sucking insects.[1]

When the method of natural infection is once learned these facts can doubtless be easily explained, but at present no theory can be offered that will account for them.

Artificial Inoculations.

The different mosaic diseases which have been investigated present very marked differences in the ease with which they may be produced artificially. At the time that these investigations were begun, (August, 1918,) only one successful inoculation experiment had been reported with the cane mosaic or yellow stripe disease, that by Dr. Kamerling in Java in 1902.[1] Later investigators in Java had been unable to corroborate this result since, according to Wilbrink and Ledeboer,[2] all subsequent attempts at inoculations had failed. Stevenson, too, in his various papers on this disease reports only failures in his attempts at inoculation. Since inoculations with diseased cane juice had given such unsatisfactory results the attempt was made to try out other methods by which the disease might be conveyed, the results of which are given in the notes on the following 21 experiments. It will be noted that three of these experiments, Nos. 1, 2 and 12, consisted in rubbing or otherwise lacerating healthy leaves with diseased tissue which is the successful method for conveying the bean mosaic. No cases resulted. Experiments 3, 5, 10 and 11 consisted in binding pieces of diseased tissue in contact with cut surfaces of healthy stalks. Out of 11 such attempts one was successful (see No. 5). In experiments 4, 6 and 8 bits of diseased tissue were dropped into the inrolled terminal leaf spindle so as to lie in contact with unwounded young tissue. Out of 60 attempts four positive cases resulted. In experiment No. 6, three out of five attempts were successful, the highest proportion in any of these experiments, yet the same method used on a large scale at Arecibo (No. 8)

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[1] Since the above was written secondary infection has developed in some of these cases.

[1] Am. Rept. Kagok Proefstation, Java, 1902.

[2] Med. Het Proefstation, Java, 1910.

completely failed. In experiment No. 7 a hypodermic needle was thrust into the soft tissue near the terminal bud of a diseased cane and was immediately inserted near the base of the inrolled leaf spindle. There was no result from 50 attempts. Experiment No. 9 was the only one made with diseased juice exposed in the open air. It was intended as a check on the following experiments, no positive results being expected on account of the failure of this method that had been so often reported. As a matter of fact two out of seven attempts developed good cases, the one in a little over three weeks, the other in between four and six weeks.

Since the disease was spreading rapidly in the fields by secondary infection and since insect carriers seemed to be the only logical explanation of this spread the attempt was made to visualize any possible differences in method between this hypothethical inoculation by insects and the previous attempts at artificial inoculation. Since young cane tissue, and to a less extent cane juice turns brown quickly when exposed to the air it seemed possible that this oxidation might affect the vitality of the mosaic virus, and that a sucking insect flying from a diseased to a healthy plant and again feeding might regurgitate a minute quantity of the diseased juice without having exposed it to the air. To test this idea the attempt was made to extract juice from diseased cane under oil to avoid exposing it to the air. In experiments 13 and 14 the technique was faulty, still one case developed in No. 4 after only two weeks incubation. In experiment 15 a satisfactory juice was obtained which remained clear and absolutely colorless under the protective oil covering. Of the ten inoculations in this experiment five developed typical cases of disease within four weeks time, and the basal suckers also showed the disease, demonstrating the fact that the entire plant had become infected. However, experiments 20 and 21 which were designed to exactly duplicate this one gave no positive cases.

Experiments 17, 18 and 19 are sufficiently explained by the notes under each. The peculiar differences in behavior of the inoculated plants in 18 and 19 can only be explained on the supposition that the virus from the diseased bits of tissue in the test tubes had propagated in the protected healthy juice and that it produced local lesions in the leaves of the plants into which it was injected even though no cases of disease were induced. The same effect was observed to a marked degree in experiment 20 and to a less extent at various other times. These observations seem to indicate that the virus may cause

temporary local lesions even when the disease does not become generalized so as to affect the entire plant.

The prompt production of diseased suckers from the base of infected stalk shows that the entire stalk must become diseased at about the time that it first becomes evident in the terminal leaves. The leaves formed before this time, however, do not show the disease but remain normal in color until they dry up. Secondary infections in the field can usually be distinguished from seed infection, for in the latter all the leaves will be affected and the growth usually stunted while in the former the basal leaves remain normal and for a time at least growth is but little checked. Then, too, in seed infection all the stalks in the stools are involved; in secondary infection at first only one or a part of the stalks show the disease. After cutting the cane all of the ratoon sprouts from an infected stool will show the disease; that is, all of those having organic connection through the old stubble. Without this organic connection two plants, one healthy and the other diseased, may grow in close contact with their roots intermingled for months or even for years without any transference of the disease.

In interpreting the above results it must be borne in mind that in practically all parts of Porto Rico there is more or less danger of natural infection. The results of all inoculation experiments made here must always be subject to more or less doubt from this cause. As a matter of fact two natural cases appeared in that part of field No. 11 where most of these experiments were made, and several others occurred in other parts of this field. In the experiments in this field where inoculations with diseased juice or diseased tissue were made in 54 stalks, 12 of them developed the disease. Several hundred stalks were included in the area where only two cases developed from natural infection. This proportion is so much smaller that we are forced to conclude that at least a portion of these 12 cases were caused by artificial inoculations. The fact remains, however, that the successes were much less frequent than the failures, that the best results could not always be duplicated, and that the successful transfer of the disease is dependent on some factor or factors as yet absolutely undiscovered.

Inoculation Experiments.

September 12, 1918.—Insular Experiment Station greenhouse, cane plants in pots.

1. Five stalks. Young leaves rubbed vigorously with diseased leaf (as in method of conveying bean mosaic). No results.

2. Five stalks. Young leaves rubbed with tissue from near the tip of diseased stalk. No results.
3. Four stalks. Cut with slanting cut and wedge of diseased tissue inserted. No results.
4. Five stalks with bits of diseased tissue dropped into the inrolled leaf spindle of terminal bud.

    On October 21 one plant in this lot was showing symptoms of mosaic and by October 26 it was a clearly developed case.

January 12, 1919.—Insular Station field No. 11, Yellow Caledonia ratoons.

5. Two stalks. Made slanting cut on side and pushed in a wedge-shaped "graft" made from the tip of a diseased cane, covered with waxed paper and tied firmly.
6. Five stalks. Dropped bits of diseased tissue in inrolled leaf cylinder of terminal bud.

    On January 31 one of the "grafts" in experiment 5 was still alive the other was dead.

    February 27, 1919. One of the stalks in lot 5 had developed a good case. The other remained negative.

    February 11. One of the plants in lot 6 show the disease.

    March 13. Two more plants in lot 6 have developed the disease and the first one shows diseased suckers at the base. The other two plants remained negative.

October 31, 1918.—Central Los Caños, Arecibo. Plant cane of Yellow Caledonia, stalks about 2 feet high.

7. Fifty stalks inoculated with needle punctures through the inrolled leaf spindle just above the terminal bud. The hypodermic needle was first thrust into the soft tissue near the tip of a diseased cane and then into the stalk to be inoculated.
8. Fifty stalks. Diseased tissue dropped into the inrolled leaf spindle.

Two or three cases of mosaic developed in each of these lots but as natural secondary infection was active fully as many cases developed in the adjoining untreated rows. The result was thereafter negative.

January 31, 1919.—Insular Station field No. 11. Yellow Caledonia ratoons.

9. Inoculated 7 canes (about 2 feet high) with hypodermic

needle, using juice from diseased cane pressed out by hand laboratory mill. The needle was thrust into the leaf spindle above terminal bud.

Februar 23, 1919. One of these cane has developed mosaic.

March 11, 1919. One more case has just developed the disease. The remaining 5 stalks remained negative.

January 20, 1919. Insular Station greenhouse.

10. "Inarched" a diseased and a health cane (both growing in pots) by cutting away about one-third of each cane for a distance of 3 inches and binding the exposed surfaces together.

The canes lived for some months but the healthy cane did not contract the disease.

January 31, 1919.—Insular Station Field 5. Spring plant cane about 7 feet high with well-developed stalks, variety P. R.–271.

11. Prepared 4 stalks by cutting out a block of cane one inch long and one-quarter to one-third inch thick with a bud in center. The space was filled with a similar block with bud in center cut from a diseased cane which was firmly tied in place and well covered with waxed paper.

These diseased blocks remained alive for some weeks but no cases resulted.

January 31, 1919.—Same field as above.

12. Two canes inoculated by placing a diseased leaf in contact with a healthy one and boring the point of a penknife through the two leaves so as to blend the tissues. No results.

January 31, 1919.—Insular Station. Field 11. Yellow Caledonia ratoons.

Since freshly cut cane tissue and cane juice oxidizes quickly with change of color when exposed to the air it was thought that this oxidation might destroy the contagion. The attempt was made to protect the juice from air by crushing pieces of cane in a morter which was partially filled with olive oil. It was difficult to get out the juice in this way and it seemed to emulsify to some extent with the oil.

13. Ten stalks were inoculated with the mixed oil and juice.

On February 8 these plants showed extensive yellow

oil-soaked areas both above and below the needle pricks. These shaded out into mottled areas and stripes looking much like incipient cases of the disease. Some of these stalks finally died from the effect of the oil but none of them developed mosaic.

February 1, 1919.—Insular Station Field 11. Yellow Caledonia ratoons.

14. Ten more stalks were inoculated with juice pressed out under gas-engine cylinder oil in a mortar. This did not emulsify but so little juice was secured that water was added in order to suck it into the needle without oil.

    February 15. One typical case had developed and was photographed. The other nine remained negative.

15. February 8, 1919. Prepared juice from diseased cane without exposure to air by taking bits of the cane in strong pincers and holding them under gas-engine cylinder oil in a beaker while pressing out the juice.

    Inoculated 10 canes about 2 feet high, Yellow Caledonia ratoons, field 11, with this juice by inserting the hypodermic needle into the leaf spindle just above the terminal bud.

    Also inoculated 7 canes in same field by inserting the needle into the midrib of young leaves. These last gave only negative results.

    March 7. Five of the ten canes inoculated in the leaf spindle on February 8 now show pronounced cases of mosaic. In three of them basal suckers are also showing the disease thus demonstrating that the entire plant quickly becomes infected.

16. February 9, 1919. With the oil protected juice prepared yesterday 3 inoculations were made in the leaf spindle of terminal bud in spring-planted P. R.–271 cane 6 feet high in field 5 C. When the new leaves developed conspicuous yellowish areas appeared both above and below the needle pricks. For some time they were regarded as incipient cases but these symptoms finally faded out and no infection followed.

17. February 12, 1919. In order to test the possibility of propagating the mosaic infection outside of the cane plant, juice from healthy cane was expressed under cylinder oil to protect it from oxidation. This juice was pipetted to test

tubes in which half an inch of oil had been placed and thus protected from contacted with the air the tubes were sterilized in the autoclave. When cool bits of tissue cut with flamed scalpel from near the growing point of diseased cane were forced under the oil in one series of tubes and corresponding pieces of tissue from healthy cane were placed in another series as checks.

The juice remained bright and clear in both series for many weeks, the only difference noted being that the bits of healthy tissue mostly sank to the bottom of the tubes while most of the bits of diseased tissue floated between the juice and the oil.

18. March 9, 1919. Inoculated 10 canes in the Yellow Caledonia ratoons, field 11, with juice from one of the tubes prepared on February 12 in which a bit of diseased cane was suspended and 10 more from one of the check tubes
19. which contained a bit of healthy tissue.

On March 15 it was noted that a number of the plants in the first series were showing local discoloration near the needle punctures but that no such discoloration could be noted in the check series.

On March 26 trifling local discoloration was noted in two plants in the checks series the remaining 8 showing only dried-down needle pricks. Five of the ten in the first series, on the contrary, showed mottled discolored areas three or four inches in extent about the needle pricks and they were noted as incipient cases. Three of the plants showed slight local discoloration only, while the other two were intermediate, but it was thought at the time that they would develop good cases. As a matter of fact, after being visible for some weeks the color finally faded out from all of these areas and no cases resulted in either series, but there can be no question as to their different behavior.

March 21, 1919.—Caledonia Ratoons, field 11.

20. Inoculated 10 canes with oil-protected juice from diseased cane (prepared as on February 8) injected into leaf spindle just above the terminal bud.

On March 29, it was noted that nine of the above inoculations showed pronounced local discolorations in the neighborhood of the needle pricks. These discolored areas

presented much the appearance of the true mosaic and in some cases they could be traced for three or four inches above and below the needle pricks. As the successful inoculations made in this same manner on February 8 had also shown these preliminary symptoms it was confidently expected that nine positive cases would result. However, after remaining visible for some weeks the discolorations finally faded out and no infections followed.

21. March 21, 1919. Six inoculations were also made with the same oil-protected juice in young ratoons in pots in the greenhouse. No cases resulted.

The results of inoculation experiments made at this station by the pathologist, Mr. Julius Matz, will be found on another page. He also had only occasional successes in communicating the disease. Details of the cage experiments with insects suspected as being carriers of the disease are given by the entomologist of the Station, Mr. E. G. Smyth, at another place in this publication. The verdict here will simply have to be "not proven."

The situation under this heading may be summarized as follows:

1st. Sugar-cane mosaic is "hereditary," being uniformly carried in diseased cuttings and always appearing in plants grown from them.

2nd. Secondary infection exists in nature and is often responsible for the rapid spread of the disease to previously healthy cane. Ordinarily it is nearby stools that are thus affected, but occasionally the disease seems to be carried for long distances. Secondary infection is more active in some localities than in others. It is also more active at some times than at others in the same locality. Insect carriers of the disease have been suspected, but so far this is not proven.

3rd. Successful artificial transfers of the disease have been made by various methods but the results have not been uniform and complete failure often results.

6th. Resistance and Immunity—Variety Studies.

The importance of this topic was early recognized and field observations were made on the behavior of the varieties to the disease at all opportunities. A few notes on the supposed resistance of certain kinds had been published by Stevenson and by Cowgill. It was, however, the finding of an apparently immune variety, the Japanese [1] Kavangire, in the experimental plots at the Federal Station

[1] Since the above was written the publication of a paper on this variety by Dr. Cross of the Argentine Station at Tucuman shows that this is a north Indian cane but that it has never been cultivated in Japan.

at Mayagüez, that focussed attention on this phase of the problem and indicated the necessity for an immediate comprehensive study of varietal resistance. Evidently plots for this purpose would have to be located in a diseased district and would have to be so planted as to subject each kind to an equal chance for infection. It was at first proposed to the Federal Station at Mayagüez that they make such a planting. No land for the purpose being available, however, an arrangement was made with the Central Guánica for putting in such an experiment at their trial grounds at Santa Rita under the supervision of Mr. Bourne, who was then in charge of their experimental work. A total of 171 kinds were planted in rows of 30 seed pieces each and every third row was planted with diseased Rayada in order to secure a uniform chance for infection. The results of this experiment were published in Insular Station Bulletin 19, where full details are given. They may be summarized by saying that the full immunity of the Kavangire cane was proven. Convincing proof of periodicity or irregularity in the activity of the infection was secured. From this cause 9 of the kinds failed to become infected. Of the remainder 40 varieties were clearly more susceptible than the Rayada; that is, they showed greater injury when attacked by the disease; 42 kinds were listed as about equal to Rayada in this respect; while 73 kinds made a somewhat better showing than the Rayada. The bulletin, however, fails to call attention to the fact that the Rayada rows are all from infected seed and that this constitutes a heavy handicap in comparing them with the other kinds, which were all secondary infections. If the experiment is continued another year the Rayada will make a decidedly better showing in the ratoon crop, which will practically all come from infected stubble. Of these 73 kinds 24 were listed as being especially resistant, or perhaps the better word would be tolerant, to the disease since, though fully infected, their growth was but little affected. Of these the best in order named were given as Java 56, Java 234, and G. C.–1313 (Guánica Central seedling). The name of the first-mentioned and most promising of these kinds needs a further word of explanation. In a footnote on page 6, Bulletin 19, the statement is made that "this is the J.–36 of the Argentine but is not the true J.–36 of Java." This was said because of the description by Noel Deerr (Cane Sugar, p. 41) of Java 36 (P. O. J.) which calls for a green cane. The finding of the very full description of this variety by Jesweit (Med. V. Proefs. V. Java-Sukerindustrie Series 1917 (No. 12, p. 6) shows conclusively that this is our cane and that its name is Java 36

Java. It is one of Kobus' seedlings having the North India variety (P. O. J.), the initials standing for words meaning Proofstation East Chunnee as staminate parent and the Black Cheribon (Louisiana Purple) as pistilate parent. The description of the green variety quoted by Deerr properly belongs to Java 36 (Bouricius), a cane belonging in a different series of seedlings and from different parentage. The careless use of the initial J. to indicate any seedling cane from Java is an error, since several numbered series of seedling canes have been produced in Java. "J–228" and "J–234" of Bulletin 19 should also be written J–228 (P. O. J.) and J–234 (P. O. J.), since they, too, are seedlings by Kobus from the same parentage. The resistance of these kinds clearly comes from the North Indian ancestry. The Japanese varieties also all came originally from northern India. Observations on another Japanese cane, the Zwinga or so-called "fodder cane" of the southern States, indicate that it, too, is immune to the mosaic, though it has not been subjected to such convincing tests as the Kavangire, which it closely resembles but from which it may be easily distinguished.

7TH. ECOLOGICAL SURVEY OF THE INSECTS INHABITANTS OF CANE FIELDS.

The importance of this topic was based on the supposed existence of some insect carrier for the mosaic disease. Field observations on cane insects have been made wherever possible and many scattered notes have been made, but the personel has been lacking for a comprehensive study of this subject. The paper on cane insects on another page by Mr. Smyth brings out many new facts and serves as an important contribution to the subject. It is indeed remarkable that the minute spring tail, which is so exceedingly common on cane leaves and which is responsible for so much of the minute spotting which is often confused with the mosaic, should never before have been recorded as a cane pest. This emphasizes the need for work in this interesting field aside from the chance discovery of a carrier for the mosaic.

8TH. CAGE EXPERIMENTS WITH INSECTS SUSPECTED AS DISEASE CARRIERS.

Much painstaking work was done on this topic both here at the Insular Station by Mr. Smyth and at the Federal Station at Mayagüez by Mr. W. V. Tower. The details of part of this work appears on other pages of this publication. Very unexpectedly, no results

at all were secured at Mayagüez and the cases of disease following colonization with insects here were so few as to be within the possibility of accidental or natural infection. The case therefore is not proven. This, however, does not preclude the possibility that an insect carrier or insect carriers exist. In fact, this hypothesis is the only one so far suggested that will account for the observed facts in the spread of the disease.

9TH. MORPHOLOGICAL, HISTOLOGICAL AND CYTOLOGICAL STUDIES OF DISEASED AS COMPARED WITH HEALTHY CANE.

A reading of the literature of this disease is sufficiently convincing that this subject is in need of study. The statement is found that infected leaves contain less chlorophyll than normal ones, but it is not clear whether this is because less is being elaborated by the chromatophores, as in etiolation from shade, or whether these bodies themselves are lacking. In discussing the stem cankers Stevenson says (Ann. Rept. 1917, p. 47):

> "Penetration of the tissues is never very deep, hardly more than from one to two millimeters at first, and is often limited to a few layers of cells only. The affected tissues are red, but not different in shade or other characteristics from similar effects produced by other causes. There are no other internal symptoms except as noted below."

In the paragraph to which this last remark seems to refer he adds:

> "In addition to the stunting or dwarfing of the stools there is a shrinking of the internodes of the individual stalks. This is especially pronounced in what might be determined third-phase cases or those in the last stages of the disease. Such stalks are almost completely lacking in juice, the limited amount of pith tissue formed being of a rubbery consistency."

This practically completes our previous knowledge of conditions within the diseased plants, so that the paper by Mr. Matz on another page of this issue constitutes a decidedly new contribution. The present writer has followed Mr. Matz's work with great interest and has seen his preparations. While the study is a preliminary one and no sweeping deductions are as yet to be drawn from it, the interesting fact remains that certain cells or groups of cells in the parenchyma of diseased stalks are filled with a peculiar granular protoplasmic substance. These plugged cells can be detected in very young tissues. They may occur at any point within the center of the stalk, and are also found in the leaves and leaf sheaths. The

cankers are formed by the final breaking down of these abnormal areas. A somewhat similar condition has occasionally been found in injured discolored tissues of canes that were free from the mosaic disease, but this abnormal condition can be distinguished from the one under discussion. These groups of abnormally filled cells at least furnish a physical basis for the disease, and that is something which has heretofore been lacking. The appearance of the abnormal material filling these cells is so much like that of a plasmodium that eager search was made for some indication of swarm spores or other fruiting bodies, but for a long time without result, the only change noted being that in the older tissues the granular appearance of the plasma became more marked as though it were becoming multinucleate. At length in an old cankered stalk that had become partially dried by lying two or three weeks in the laboratory it was observed that the entire plasmodium had broken up into minute, irregular, rod-shaped bodies, some of which showed X and Y forms. These minute rods were motile, revolving slowly on their axes so that the whole mass was clearly agitated but there was little active movement of translation. Taken alone, these bodies would unquestionably be called bacteria, but ordinary bacteria are not formed from a plasmodium that exists in that form for weeks and months. A similarity to the parasitic genus *Plasmodiophora* among the slime moulds is clearly suggested, but these motile bacteria-like bodies are very different from the regular globose spores of that genus. Perhaps the nearest parallel is furnished by the nodule-forming organism of the *Leguminosæ,* where the first stage is a zoogloea mass within the young root cells, but this very early breaks up into the irregular rods that in shape and behavior closely resemble those of the organism under discussion. For the present it seems best to withhold any positive statement as to its true systematic position. No causal relationship with the mosaic disease has as yet been proven, but at least the presence of this peculiar organism seems to serve as a diagnostic character of importance and one that has heretofore been overlooked.

10th. Studies on the Nature of the Disease and Search for a Casual Organism.

The close relation of this topic to the last one is easily recognized. The nature of the disease has also been discussed in the paragraphs on natural and artificial infection where we have seen how persistently it has been regarded as a degeneration, bud variation or

abnormality. Nothing can be more clearly proven than that it is an infection, so these earlier views now have only an historical interest.

The proper name to be applied to this disease demands a moment's discussion. The Dutch investigators in Java have called it "Gele Strepenziekte," or as literally translated by Hawaiian writers, "Yellow Stripe Disease."[1] This is clearly the earliest name applied to it in scientific literature and if priority is insisted on it must be recognized. Unfortunately, it is misleading since in the great majority of cases no striping effect is produced. Stevenson's name of "Mottling disease" is much more truly descriptive. In its Spanish form, "Matizado" it has come to be the universally recognized term for it in Porto Rico. The present writer is responsible for adding still another name, "Sugar-Cane Mosaic" (Insular Station Circular 14:6), but he has always used it as a descriptive phrase in connection with one or both of the other names, intending by so doing to convey some idea of its general nature and relationship. The mosaic diseases are an obscure class of poorly understood disorders on which there has come to be a considerable literature. While there are well-marked differences among them they seem to have much in common. Whichever term we may prefer as the specific name of this cane sickness the fact will remain that to the best of our present knowledge it is a mosaic disease.

The real nature of this class of disorders has been the subject of much discussion. Very divergent views have been held regarding them and it must be admitted that even at the present day pathologists are by no means in full accord regarding them. A few years ago it was the fashion to ascribe them to an abnormal secretion of enzymes produced in some inscrutible manner by a change in the internal functions of the plant. They were considered functional diseases. It is easy to understand that sudden changes in environmental conditions might induce functional disorders. It is well known, in fact, that this is the case. Many such invironmental diseases are known but none of them are contagious. No satisfactory explanation has ever been given of how a disease may be conveyed from a sick plant to a healthy one except by means of living parasitic organisms. The advocates of the above theory have therefore always sought to minimize the evidence of infection and to account for the

[1] Stevenson even in his latest paper, *Journ. Dept. Agric. of Porto Rico,* III (No. 3), July 19, is unwilling to admit that the identity of this with the Porto Rican disease is proven. The fact that so many outbreaks in different parts of the world can be traced to importations of Java seed cane together with the internal evidence from the descriptions and illustrations in the Java literature leaves no possible doubt in the mind of the present writer that Lyon is absolutely correct in considering them as identical.

spread of these diseases on the ground of inherited predisposition or, in other words, by degeneration and abnormal bud variation. As we have seen in the foregoing pages, the evidence of the infectiousness of this cane disease is overwhelming. It is equally convincing in regard to all of the other mosaics that have been studied. Recently this has lead to the rather wide acceptance of the idea that they are caused by ultramicroscopic parasites—the hypothesis held to-day by human pathologists to account for contagious diseases such as smallpox and various others, for which no parasites have yet been discovered. It is certainly true that no ordinary bacteria or fungus hyphae can be found in the diseased cane tissues except those that are clearly secondary in very old cankers, and no such organisms can be cultivated from them by ordinary laboratory methods. It can be safely affirmed that the mosaic diseases are not caused by ordinary bacteria nor by filamentous fungi. Of course, we know that chemical atoms and molecules are far too small to be visible under the microscope. There is nothing impossible in the conception of living bodies so small, that like the atoms and molecules we can only know them by their effects. On the other hand, we may have the alternate conception of a naked-celled amoeboid parasite not so small but so similar in structure to the other protoplasmic contents of the plant cells that it has so far escaped detection. A living virus seems to be necessary in order to account for the spread of infectious diseases. When we cannot demonstrate one we are forced to imagine one. It is not yet proven, that the plasmodium-forming organism referred to under the last heading as having been uniformly found by Mr. Matz in mosaic disease tissue, is the real cause of the sugar-cane mosaic though the evidence so far points strongly in that direction. If this proves to be so this will be a case of a different kind where a comparatively large and conspicuous organism has been overlooked by a long series of pathologists simply because it is a strict parasite of an unusual kind and one that cannot be grown on ordinary culture media.

The general symptoms of this disease have been described so often that it seems unnecessary to repeat them here. Mr. Matz's paper shows that the lesions leading to the formation of cankers when near the surface of the stalk are also deep seated, and on their final collapse leave internal cavities which account for the light weight and lack of juice in the infected canes. These studies also show that the stuffed parenchyma cells that constitute the earlier stages of

these lesions can be detected in the very young tissue of the stalk and also in the young tissues of the leaf sheaths. In many varieties the more superficial ones may be detected with a hand lense in the very young and still soft internodes. This paper also shows that in the discolored areas of the leaves there is a lack not only of chlorophyll but of chloroplasts. These points should be added to the descriptive diagnosis of the disease. The fact should also be restated in this connection that in cases of recent infection the disease often appears in basal suckers within a few days of its appearance in the young terminal leaves although the matured leaves farther down on the stalk never develop the diseased symptoms. This shows that the infection has really invaded the entire stalk and the growing point of all the buds almost simultaneously.

Attention should be more forcibly called to other leaf spottings and discolorations that may be confused with the mosaic symptoms. In the course of these investigations the fact has developed that cane foliage is often attacked even in the unrolled bud spindle, by great numbers of several species of minute insects and mites which cause very considerable damage through the minute spotting of the leaves. Singularly enough, this damage has escaped the attention of the entomologists and some of the species are listed as cane insects for the first time in Mr. Smyth's paper on another page of this issue. Later these minute discolored specks often become invaded and enlarged by one or another facultative fungus parasite. We have a considerable literature on cane leaf spots as caused by fungi but there is little in print to show that in practically all cases the inciting cause of the spotting was the puncture of some minute insect. This however is the fact. In the later stages when invaded by fungi these leaf spots are sufficiently different from mosaic and there is no danger of confusing them. Many times, however, especially in old fields where the foliage is yellowish from root disease and bad cultivation, this minute insect spotting on the young unrolling leaves is sufficiently like the first indications of incipient mosaic infection to be very confusing. The mosaic disease, if present, however, very soon shows itself unmistakably and there is seldom any practical difficulty in distinguishing it. In examinations to determine the presence of mosaic disease attention should always be given to the youngest leaves, and especially to those not fully unrolled.

In all of his writings on the subject Stevenson has insisted on a three-year phase for this disease and he only describes the cankers

as occurring in the third or final stage. The present writer has been unable to confirm this view. The response of different varieties when attacked by the disease is so different that no general statement of this kind is possible. For instance, in the Santa Rita immunity experiment the Yellow Caledonia variety which was attacked by secondary infection soon after germination, developed serious stem cankers within six months and a number of the attacked stools were actually killed before the final inspection at the end of ten months. This was an extreme case but it is only one of many that show that the three-year phase idea is untenable. There is, however, usually a well-marked difference in the effect on the plant between primary infection from a diseased seed piece or diseased stubble and cases arising from secondary infection. In the former cases, except with the very resistant kinds like Java 36 (P. O. J.), which are scarcely affected by the presence of the disease, there is a pronounced dwarfing and all of the leaves on all of the shoots are equally affected. In secondary cases there is at first but little dwarfing and only one or a few of the stalks in the stool are involved. It is true that the course of an invasion by the disease has often resulted in what amounts to a three-year phase. In the first year a few scattered cases have appeared, perhaps by secondary infection but only too often from the criminally careless use of infected seed for replanting previously healthy ratoons. By the second year these cases have spread quite widely by secondary infection, but being secondary cases with a semiresistant variety like Rayada the damage has been comparatively slight. This would correspond to Stevenson's secondary phase. The following year with a considerable percentage of cases from diseased stubble the dwarfing effect would be much more obvious and losses of weight from cankered stalks would be much greater. With susceptible varieties like Otaheite, Cavengerie and Caledonia, this may end the productive life of the field, but as seen on page 9, fields of Rayada are known that though fully diseased for years at the fifth cutting gave as high as 20 tons of cane per acre in response to better cultivation and fertilization. That many diseased fields became valueless after the third year is freely admitted, but that the disease presents any approach to a three-year cycle must be strenuously denied.

11th. Chemical Studies of Diseased as Compared with Healthy Cane.

The papers by director Colón and by Mr. López on other pages

of this issue are contributions to this subject. While the investigations have so far only been of a priliminary nature, they show no very striking chemical changes as a result of the presence of the disease. The earlier published statement that the diseased cane was very objectionable in the mill can refer only to those extreme cases where the cane became badly cracked. It seriously affects the quantity of the juice rather than its quality. Very much more than half of the cane ground this last year at all of the mills from Arecibo westward was diseased. The statistical report on sugar manufacture in Porto Rico issued by the Department of Finance gives for the 1919 crop not only the tons of sugar produced at each of the mills but the number of tons of cane ground. By averaging these figures for eight of the mills in the worst infected district we find that it required 9.88 tons of cane to produce a ton of sugar. At five representative mills from the eastern district where there was little or no disease the average was 9.32 tons of cane to the ton of sugar. So small a difference as this could easily be accounted for by differences in mill equipment and extraction or by weather conditions in different parts of the Island.

12TH. SOIL STUDIES: EFFECTS ON THE DISEASE OF DIFFERENT SOILS, SOIL STERILIZATION, SPECIAL FERTILIZERS, TOPICAL APPLICATIONS.

But little has been done under this heading. Field observations in all parts of the Island demonstrate that soil conditions have nothing to do with the spread of the disease. It is to be found on all types of soil on which cane is planted. Emphatically it is not a soil disease. On the other hand, good soils, abundant nitrogenous fertilizers and good cultivation while they will not ward off the disease will increase yields of cane that has become diseased. Many planters believe that liming the soil has some effect in preventing the disease. So far we have no exact facts in support of this theory.

An experiment was planted with the kind coöperation of Russel & Co. to test the effect of lime and sulfate of iron in combination with different fertilizers as follows:

Plot 1 at rate of 400 pounds tankage per acre.
Plot 2 at rate of 800 pounds tankage per acre.
Plot 3 at rate of 1,200 pounds tankage per acre.
Plot 4 check, no fertilizer.
Plot 5 at rate of 800 pounds tankage and 400 pounds sulfate of potash.
Plot 6 at rate of 800 pounds tankage and 400 pounds sulfate of amonia.
Plot 7 at rate of 800 pounds tankage and 800 pounds acid phosphate.

These plots were cross divided by three bands one of which received at rate of 4 tons of lime per acre, one 500 lbs. iron sulfate and the other no application. The intention was to have these plots planted with diseased Rayada seed cane. By some accident the seed selected was only about half diseased so that the cane came up very irregularly infected. The soil, too, developed unexpected irregularities in fertility before the fertilizers were applied. It is not expected, therefore, that this experiment will give conclusive results. At this writing it can only be said that the heavy applications of fertilizer have given a very heavy growth, but no very specific results can be noted from the different treatments. These plots will be cut and weighed when fully mature.[1]

13th. Relationship with Other Similar Diseases—A Comparative Study of the Mosaic Diseases.

Nothing has been done under this topic.

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[1] A later inspection indicates a deleterious effect from the sulfate of iron and no appreciable effect from the lime.

THE MOTTLING DISEASE OF CANE AND THE SUGAR PRODUCTION OF PORTO RICO.

By C. A. Figueroa.

Since the year 1915 the cane growers of Porto Rico have been complaining that the sugar production of the Island has been diminishing with every succeeding crop. About the same time it was noticed that the fields were taking a yellowish color, the growth seemed to be handicapped, the stems were beginning to shrink and crack, and finally that the cane production per acre was getting to be less and less. To the disease presenting these symptoms was given the name of ''matizado'' or mottling disease.

A great many efforts have been made to control this disease, but so far they have proved to be of little value. To-day every cane-growing section of the Island is more or less infected.

About a year ago the students of the disease stated that the infection was ''very general in the cane fields to the west of a line drawn from Bayamón on the north coast down to Guánica on the south coast.'' Only isolated cases were found to the east of this line. The progress of the disease since then is best shown by the following letter:

''My Dear Mr. Figueroa:

''In reply to yours of September 8, inquiring about the present extent of infection with *matizado* in the different cane-growing districts, I would say as follows:

''From Bayamón to Barceloneta on the north coast infection is as yet only partial, but the disease is sufficiently abundant to constitute a commercial factor of importance. Your investigation will probably show some effect of the disease in lessening production in this district. As a rule the hill lands are more heavily infested than the *vegas.*

''From Arecibo to Central Coloso on the west coast the per cent of infection is considerably heavier than in this first district, but it is not total in all the fields, especially near the coast. Back in the hills the infection is very severe and very many hill fields have been abandoned.

''From Rincón around the west coast to San Germán the infection may be considered as total. Many of the fields are actually 100 per cent infested and very many over 90 per cent infested. It is doubtful if any field can be found that is not more than 50 per cent infested.

''From San Germán to Peñuelas the infection is very general and is now spreading more rapidly than in any other part of the Island. It is not yet, however, as complete as in the western district.

"At Central Mercedita near Ponce and in the fields about Juana Díaz there is considerable infection, but in the remainder of the south coast from Ponce to Patillas while the infection occurs locally at many places there is as yet too little to be a commercial factor.

"The same can be said of the entire east coast, though local outbreaks have occurred at Naguabo and Fajardo.

"Cayey is heavily infested.

"The district from Caguas to Juncos is partially infested but not sufficiently as yet to affect total yields very seriously.

"There is also a local outbreak at Trujillo Alto which extends to the neighborhood of Carolina.

"The above data, in connection with the other statistics you have gathered, should show quite conclusively the actual losses due to the *matizado*. I shall be very much interested to see your conclusions.

"Yours truly,

"(Signed) F. S. EARLE,
"*Expert in Cane Diseases.*"

The statistics that Professor Earle alludes to may be found in table form on page 40.

It will be noticed that the cane-growing zone of the Island has been divided according to Professor Earle's letter. A glance at the statistics will show that where the infection is most intense the sugar production has diminished most heavily.

The first section, which Professor Earle calls partially infested, (first zone) increased its acreage by over 4,400 *cuerdas* in 1918, nevertheless its sugar production was diminished by 2,850.31 tons. This figure represents 4½ per cent of the 1917 crop for the zone. The following year the acreage was diminished by over 450 *cuerdas* and then the loss of sugar goes up to about 18.3 per cent of the 1917 crop. It will also be seen that there is no proportion between the fluctuations in acreage as compared with the sugar output.

In the section from Arecibo to San Sebastián the infection is still greater than in the preceding one. Of this section Dr. Blouin of Louisiana says the following:

"In the district between San Pedro and Mayagüez, particularly in the Arecibo district, the damage has been very extensive. I visited three or four plantations in that district and the damage amounted to 40 per cent of the crop." —(*La. Planter and Sugar Manufacturer*, Oct. 18, 1919.)

The statistics show that this section has seen its sugar production reduced by about 40 per cent in two years.

The section from Rincón to Lajas offers a conclusive proof of the extent to which this disease interferes with production. In one year the sugar output is cut down to 67.6 per cent of the normal

and the next year it goes further down to nearly 60 per cent. This clearly shows the rapid progress of the disease in one year.

This has been partly due to the fact that seed has been very scarce in that section and lots of diseased seed have been used. These could be bought at very low prices. The writer in his report on a trip throughout this section was informed of this fact:

> "The fact that cane seed (cuttings) are being sold at a very low price in the San Germán valley induced me to look into the matter somewhat carefully. After some investigation I found healthy seed was exceedingly scarce in that section and this led many planters to use diseased seed which they can get at very low prices, thus helping to spread the disease in the most efficient manner. Lots of these diseased seed have been sold to the planters at Sabana Grande."

The section from Sabana Grande to Peñuelas has lost considerably. In this district, as in the first one here discussed, the infection has increased very rapidly and the losses in sugar have also increased accordingly.

In the south and east coasts of the Island the disease is only beginning to show. Losses here are greatly due to the lack of rainfall.

All students of this disease agree that its attacks are more severe in the hill plantings than in the lowlands of the coast. The Cayey and Adjuntas section prove this conclusively.

"The disease reduces the tonnage and therefore also reduces the production of sugar per acre." This statement was made by the director of the Insular Experiment Station in his Circular No. 14, and to back up his utterance he mentions the following experiences:

A Java experiment gave these results:

Healthy cane, 21.23 tons per acre, first crop.
Mottled cane, 18.20 tons per acre, first crop.

Results of a Hawaiian Experiment.

	Tonnage of 3 rows 80 feet long	Estimated tonnage per acre	No. of canes	Average weight per cane (lbs.)	Tons of sugar per acre
Healthy cane......	2.786	101.13	835	9.27	14.98
Mottled cane......	1.5495	56.24	623	8.01	8.43

OTHER CONDITIONS AFFECTING THE SUGAR PRODUCTION.

This work will not be complete if it does not contain a brief discussion of all factors that may have had some influence on the sugar production. The writer does not pretend to assume that every pound

of sugar lost has been due to this disease. Though he firmly believes that the bulk of the loss is the result of the *matizado,* there are other causes to be taken into consideration.

RAINFALL.

The rainfall records available are not complete and for this reason they do not appear in this work. However, it is a well-known fact that the severe drouths that have occurred in different sections of the Island, particularly in the south coast and in the Arecibo-Aguadilla section, have contributed to lower production. Furthermore, the scanty amount of rainfall in certain sections like the eastern coast have come just at the wrong time.

But even so, it is not reasonable to blame the lack of rainfall for the whole trouble. The precipitation records that are complete show that there is no uniform relation between production and rainfall.

MANURES.

The following table [1] shows the importation of commercial manures by the district of Porto Rico during the last three years:

Year.	Tons.	Value.
1915–16	39, 702	$1, 735, 391
1916–17	45, 769	2, 827, 796
1917–18	40, 811	2, 929, 726

This table shows that in the year 1917–18 the imports were cut down by 5,000 tons. It also shows that the cost of commercial manures has gone beyond the reach of the small cane grower.

But if the small planter has not used as much commercial manure as before the war, he has used more stable manure, guano, etc. Moreover, the manure-mixing plants of the Island have increased their capacity to a considerable extent, and consequently lots of manurial ingredients have been imported. It is very probable that all of these ingredients have not been imported under the head "Manures" or "Fertilizers" but as "Chemical Products." The enormous increase of importations under this heading appears to confirm this belief.

On the other hand, these 5,000 tons that were not imported last year are largely potash. All commercial manure users have missed this ingredient in their manures. This has led them to believe that lack of potash is to be blamed for the deficit in the sugar production.

However, manurial experiments on record in Porto Rico as far

[1] Customs House records.

back as 1910 have failed to show the economic advantage of the use of potash as a fertilizer in cane cultivation. Professor Earle says in connection with the use of potash:

> "Potash should not be taken into consideration for its need is not so essential. Experiments with cane in Porto Rico show that the use of potash in these soils is of no such a great need. The demand for potash as a manure is one of the things 'Made in Germany.' Its use has been extended by means of the active propaganda of the 'German Kali Works.' For a good many years previous to the war this firm has been paying specialists in almost every agricultural country, whose business it was to work in favor of the potash." (Circ. No. 17, Ins. Exp. Sta., Recomendaciones sobre el Cultivo de la Caña en Puerto Rico.)

TILLAGE AND CULTIVATION.

All those interested in agriculture in Porto Rico agree in that our methods of tillage and cultivation are rapidly and constantly improving. A trip through the cane section will convince anybody of this fact. Soils are better prepared; more attention is paid to manurial and cultivation problems; seed selection is beginning to be popular; the sight of implements such as the tractor, the harrow, the disc plow and others is familiar now-a-days; and in short, the sugar men are beginning to realize that sugar cannot be made in the factories if proper attention is not paid to the agricultural end of the sugar business.

Comparing the acreage with production for the last three years we have—[1]

Year	Cane acreage *Cuerdas*	Total sugar output *Tons*	Tons of sugar per acre	Per cent decrease
1917	205.106	503.081.18	2.41	....
1918	256.431	453.975.55	1.77	9.7
1919	238.901	406,000.00	1.70	19.0

[1] From Bureau of Property Taxes and Report of the Treasurer.

This means that, taking the crop of 1917 as a basis for calculation, Porto Rico has lost 146,186.81 tons of sugar in two years. This is about equal to 30 per cent of its normal production for one season. The figure is large enough to command some attention.

COMPARATIVE STATISTICS OF THE CANE ACREAGE AND AMOUNT OF SUGAR MANUFACTURED IN PORTO RICO IN THE CROPS FROM 1917 TO 1919.[1]

Zone	Municipality	Acreage of cane 1916-17	Acreage of cane 1917-18	Acreage of cane 1918-19	Central	Sugar produced (T. 2,000 lbs.) Crop of 17	Sugar produced Crop of 18	Sugar produced Crop of 19	Decrease—T. 2,000 Crop of 18	Decrease Crop of 19	Decrease total	Per cent decrease 1918	Per cent decrease 1919
First Zone	Bayamón	2,116	2,840	2,869	Juanita	6,520 00	7,510.00	7,092.50					
	Toa Baja	3,302	4,284	4.023	Constancia	7,759.55	8,573.75	6.913.25					
	Toa Alta	975	1,406	1,355									
	Dorado	2,224	3 024	2,950									
	Vega Alta	1,069	2,346	2.196	Carmen	11,024.00	10.059.88	8,400.00					
	Vega Baja	4.464	4,008	3,957	San Vicente	12.044.00	10 925.00	10,379.00					
	Manatí	3.587	3,847	3,719	Monserrate	7.171.00	6,612 63	5.276 00					
	Barceloneta	4,038	4.419	4,648	Plazuela	16,500.00	14,487.88	11,749.00					
	Totales	21,775	26,174	25,717		61.019.55	58,169.24	49.809.75	2.850.00	11,209.80	14,060.11	4.6	18.3
Second Zone	Arecibo	11,872	14,687	13,811	Cambalache	23.129.00	15,197.63	11,021.00					
					Caños	6,353.68	5,129.38	4.375.25					
	Hatillo	1,973	3,718	3,616	Bayaney	745.00	946.00	1,367.50					
	Camuy	2,788	3,972	3,956	Soller	1,010.00	769.00	458.00					
					Alianza	4,808.00	2,343.51	1.243.00					
	Quebradillas	1,384	2,090	1,970									
	Isabela	1.018	1,567	1,527									
	Aguadilla	3,362	3,786	3,609	Coloso	13,501.50	12,690 06	11.021.00					
	Aguada	3.459	2,988	4,226									
	San Sebastián	835	1,380	1.313	Plata	1.795.60	1,854.00	1,462.00					
	Totales	26,691	34,189	34,028		51.312.78	38,929.58	30,947.75	12,413.00	20.395.03	32,808.23	24.1	39.7
Third Zone	Rincón	1,526	1,672	1.952	Córsica	11,044 00	7,581.00	7.392 88					
	Añasco	5,033	4,809	4,890									
	Mayagüez	4,968	4,166	4,284	Rochelaise	7,284.00	5,200.00	4.744.00					
					Ana María	7.993.38	5.135 00	3,969.89					
	Hormigueros	3,438	3.834	3,863	Eureka	6,084.00	3,980.00	3.527.00					
	Cabo Rojo	6,878	7,563	7,626									
	San Germán	4,688	6.635	6,631									
	Lajas	8.073	6,353	6,339									
	Totales	34.604	35.033	35,587		32,405.38	21,896.00	19,633.77	10,609.38	12,771.61	23,380.99	32.4	39.4
Fourth Zone	Sabana Grande	1,466	1,881	2,054									
	Yauco	1.779	1,746	1,623									
	Guánica	3,193	4.281	4,317	Guánica	81.000.86	76,689 86	65,685.00					
	Guayanilla	1,890	1,857	1,904	Rufina	7,900.00	7,012.00	6.438.45					
					San Francisco	3,000.00	2,666.00	2.740.00					
	Peñuelas	1,609	1,848	1,991									
	Totales	9,937	11,613	11,889		91,900.86	86,367.86	74,863.45	5,533.00	17,037.41	22,670.41	6	17.4

Fifth Zone	Ponce	10,473	9,466	9,540	Mercedita	10,204.00	9,523.00	8,593.03	....	....	....	......	......
					Constancia	2,208.00	4,508.73	1,590.00	....	....	....	......	......
	Juana Díaz	8,113	8,117	8,195	Boca-chica	14,925.00	16,231.00	13,180.00	....	....	....	......	......
	Villalba	....	596	582	....	....	....	....	....	....	....	......	......
	Santa Isabel	6,896	7,692	8,231	Cortada	10,780.00	11,173.00	8,932.00	....	....	....	......	......
	Salinas	5,446	6,218	6,262	Aguirre	48,900.00	47,200.00	44,632.00	....	....	....	......	......
	Guayama	8,580	7,447	7,237	Machete	10,557.00	10,237.00	9,845.00	....	....	....	......	......
	Arroyo	2,622	2,775	2,766	Lafayette	8,685.00	7,826.00	13,093.75	....	....	....	......	......
	Patillas	3,629	3,246	3,088	Providencia	5,200.00	4,[illegible]65.00	....	....	....	....	......	......
	Totales	45,759	45,587	45,907	....	111,457.00	111,463.73	99,365.78	....	11,081.22	11,074.49	......	10.8
Sixth Zone	Cayey	982	1,745	1,757	Cayey	5,221.00	2,778.00	2,636.00	2,443.00	2,585.00	5,028.00	46.7	50.0
Seventh Zone	Maunabo	2,865	2,151	2,142	Columbia	7,223.50	6,052.00	5,189.00	....	....	....	......	......
	Yabucoa	4,980	8,900	7,205	Mercedita	17,285.00	13,724.24	12,447.65	....	....	....	......	......
	Humacao	5,679	7,440	8,286	Ejemplo	6,276.00	6,074.00	5,152.00	....	....	....	......	......
					Pasto Viejo	11,456.87	10,777.00	9,681.13	....	....	....	......	......
	Las Piedras	2,192	3,054	1,773	....	....	....	....	....	....	....	......	......
	Ceiba	3,057	3,816	3,429	....	....	....	....	....	....	....	......	......
	Naguabo	4,601	5,840	6,149	Triunfo	1,276.25	3,203.00	3,254.88	....	....	....	......	......
	Fajardo	3,978	6,336	4,516	Fajardo	29,343.82	35,818.00	31,193.00	....	....	....	......	......
	Totales	27,352	37,537	33,500	....	72,871.44	75,648.37	66,917.66	....	....	....	......	......
Eighth Zone	Caguas	2,909	5,440	5,424	Santa Juana	11,114.00	7,187.00	7,031.00	....	....	....	......	......
	Gurabo	2,491	3,393	2,869	....	....	....	....	....	....	....	......	......
	Juncos	1,625	3,064	2,374	Juncos	14,925.00	16,231.00	13,180.50	....	....	....	......	......
	San Lorenzo	1,142	1,229	1,229	....	....	....	....	....	....	....	......	......
	Totales	8,167	13,126	11,896	....	26,039.00	23,418.00	20,211.50	2,621.00	5,827.50	8,448.50	10	22.2
Ninth Zone	Río Piedras	3,280	4,467	4,584	Vannina	10,548.00	12,135.25	11,733.25	....	....	....	......	......
	Guaynabo	1,197	3,379	2,600	....	....	....	....	....	....	....	......	......
	Carolina	2,925	4,445	3,716	Progreso	6,335.00	5,704.63	5,485.39	....	....	....	......	......
	Trujillo Alto	1,013	1,549	1,531	....	....	....	....	....	....	....	......	......
	Loíza	3,388	5,464	3,553	Canóvanas	14,703.13	15,413.50	15,184.25	....	....	....	......	......
	Río Grande	3,193	3,898	3,895	....	....	....	....	....	....	....	......	......
	Luquillo	2,895	4,151	4,209	....	....	....	....	....	....	....	......	......
	Totales	17,891	27,353	24,091	....	31,584.13	33,253.38	32,402.89	....	....	....	......	......
Tenth Zone	Jayuya	36	334	425	Santa Bárbara	957.00	798.65	585.28	....	....	....	......	......
	Adjuntas	477	444	426	Pellejas	373.00	235.00	284.00	....	....	....	......	......
	Totales	513	778	851	....	1,330.00	1,033.65	869.28	296.35	460.72	757.07	22.2	34.0

[1] From Report of the Treasurer of Porto Rico, statements of the Bureau of Property Taxes and figures from the Sugar Producers' Association.

THE ABSORPTION SPECTRUM OF THE CHLOROPHYLL IN YELLOW-STRIPED SUGAR-CANE.

By E. D. Colón.

Yellow stripe of sugar-cane is essentially characterized by the mosaic effect produced in the chlorophyll-bearing tissues, and more especially in the leaf blades, by the unequal intensity of the green color in those tissues. This unevenness in intensity is exhibited in areas whose size and pattern vary under different conditions. It ranges from deep green through shades of green, to almost white, and postulates a diminution in the amount of chlorophyll present in the lighter green areas and its almost total absence in the almost white areas.

In only two general ways could the disappearance of the pigment primarily be brought about: (1) By alterations involving the chlorophyll itself; (2) by alterations involving the chlorophyll-bearing bodies, the chloroplasts. The fact that red canes are also decolorized by the disease and, furthermore, that the young, uncolored internodes of certain varieties frequently exhibit faint purplish-red stripes when diseased, suggested an investigation of the possibility of the first alternative—*i. e.*, a general derangement of the chromogenic function in yelow-striped canes. Widbrink and Ledeboer [1] remark in this connection that in some leaves of young plants of the variety G. Z.–247 so much red coloring matter is formed under the influence of the disease that the blades take on a light chocolate tint against which the yellowish stripes and spots stand out. They further state that the cause of the striping in the stems is not due to the same cause in all varieties of sugar-cane and that in the varieties G. Z.–100, 247, 1639, 161, Yellow Batjam and many others the striping is due to the formation of anthocyanin.

Anthocyanin, carotin and xanthophyll, as well as many of the decomposition products of chlorophyll, are known to have characteristic absorption spectra. *Prima facie*, therefore, there appeared to be a strong possibility of any such wholesale modification of the normal chromogenic condition of the cane being detected by comparative spectroscopic examination of the extracted chlorophyll from both healthy and diseased leaves.

[1] Numbers in parenthesis refer to literature cited in bibliography appended.

Only newly attacked leaves were used. They were for a short time and separately extracted with ethyl alcohol after initial heating to boiling. Deep green, fluorescing solutions were obtained of each and their concentration equalized by comparative examination in the colorimeter. The spectroscopic examination of the ethyl chlorophyllide in solution was in all cases made through a ½ millimeter aperture of the jaws of the slit. Electric light was used for the illumination, the temperature of the air surrounding the globe next to the slit being from 30 to 35 degrees centigrade. The dilutions and thicknesses of solution examined will be seen in diagrams given below of the absorption spectrum repeatedly obtained.

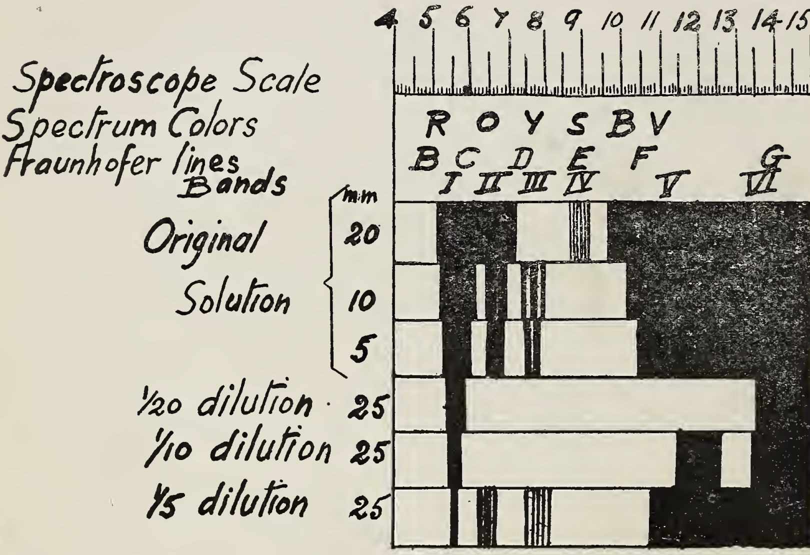

FIG. I.—Absorption spectrum repeatedly obtained by spectroscopic examination of young normal and yellow-striped sugar-cane leaves. The thickness of the layer employed is shown at the left in millimeters; the conventional letters of the Fraunhofer lines are at the top, so also the initials of the spectral colors, the spectroscope scale and the Roman numbers for the absorption bands. Aperture of the slit about one-half mm.; air temperature, 30°–35° C.

It will be apparent after glancing over the diagram that different dilutions and thicknesses of the chlorophyll solutions had to be examined before all the absortion bands could be made out. The absorption area in the more refrangible portion of the spectrum (including bands I, II, III) as well as that in the less refrangible portion (including bands V, VI) were present in all cases, their ex-

tension and distinctness depending on the conditions of examination. Band IV in the middle portion of the spectrum appeared to be the faintest of all, it having been distinctly brought out only in the most concentrated solution and when examined through the second greatest thickness employed (20 millimeters). The resolution of absorption area I, II, III into its three bands was brought about by examination of smaller thicknesses of solution (10 millimeters and 5 millimeters); that of absorption area V, VI by dilution combined with a larger thickness (25 millimeters).

It seems worth noting that band IV has been reported above as a faint band, the faintest of all, not as a dark one as represented in many discussions on the chlorophyll spectrum. In regard to this matter Dr. Edward Schunck states (2): "It should be mentioned that some of the absorption spectra figured in memoirs on chlorophyll really belong to the derivatives of the latter. Whenever in such figures band IV appears rather dark and is followed by another dark band nearer the blue end, we may conclude that the observer has worked with a specimen of chlorophyll that has undergone some change." The dark band nearer the blue end to which he refers has not been reported here as a distinct band, because although the absorption area V, VI may extend to that portion of the spectrum, we have not, nevertheless, been able to make it out as a separate band on further dilution as has been the case with bands V and VI. This has reduced to only six the total number of absorption bands reported here for chlorophyll in ethyl alcohol. Schunck (2), Allen (3), Palladin (4) and Pierce (5) report this number as six. Green (6), Goodale (7), Vines (8), Carracido (9) and Willstätter (10) report seven. Jost (11), reports a total of six, three before F and three beyond F, considering band IV before E as due not to chlorophyll but to a decomposition product of chlorophyll.

The absorption spectrum obtained for chlorophyll can thus be seen to have been fairly typical.

Now, the absorption spectra obtained for the alcoholic (ethyl) solution of chlorophyll from newly yellow-striped young leaves did not in our tests and under the same conditions exhibit any difference from the absorption spectra obtained for the alcoholic (ethyl) solution of healthy young leaves.

The four bands as figured in the diagram in the more refrangible portion of the spectrum are specially characteristic of chlorophyll. They constitute a certain test for this substance; so much so that Schunck (2), referring to the fact, says that chlorophyll "may ac-

cordingly be defined as the substance which in solution shows this particular absorption spectrum."

Should there have occurred any decomposition of the chlorophyll in the diseased leaves, the absorption spectra obtained from the examination of the alcoholic solution of their chlorophyll would not have, in the first place, been identical with the absorption spectra similarly obtained from healthy leaves. New bands or a modification of the old bands would in all probabilities have been noted, since other cane pigments and many decomposition products of chlorophyll are known to have characteristic absorption spectra. The fact that the decomposition of the chlorophyll would, in the case of the sugar-cane, have developed in an acid medium would have defined all the more the changes to be expected since the acid decomposition products of chlorophyll are fairly well known.

Although the tests above described were not as numerous nor performed with as many solvents as might have been desirable, they warrant the belief that the disappearance of the pigment in yellow stripe is not primarily due to a decomposition of the chlorophyll as such.

(To be continued.)

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HAS "YELLOW STRIPE" OR "MOTTLING" DISEASE ANY EFFECT ON THE SUGAR CONTENT OF CANE JUICE?

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Very early in the investigation of this disease the question arose as to its effect on the sugar content and purity of the juices of canes affected by it. From some quarters the claim was made that considerable inversion occurred in the juices of diseased canes and that consequently there was a great loss of sucrose and that much trouble ensued in the process of manufacture, especially at the crystallizing pans and at the centrifuges. An investigation of the point raised was therefore necessary. An attempt was made to find literature containing data that would bear on the question but with no practical results. Only two references to the subject could be found: One in The Hawaiian Planter's Record, Vol. X, No. 5, page 321, where two analyses are given, one of healthy and the other of diseased canes, in which both samples show practically the same sugar content, while the diseased canes show a higher purity; the other is a general statement in the report on the disease by G. Wilbrink and F. Ledeboer of the Java Experiment Station, to the effect that canes from diseased seeds produced, in their experiments, an average of 17 per cent less sugar than canes from healthy seeds. There is no indication, however, to show whether this loss was due to a reduction in the sugar content of the canes or to a decrease in tonnage. It was necessary, therefore, to plan for an investigation of the subject.

Some preliminary work had been done, but of very little value, so far as a definite conclusion on the subject was concerned. Some samples had been submitted to this division for analysis by Mr. J. A. Stevenson, then pathologist at this Station, in July and November of 1917. Mr. E. D. Colón, at that time working on the disease for the Division of Pathology had performed a number of analyses on healthy and diseased canes, and in a number of instances samples had been sent from plantations to have comparative tests made. The results of the samples submitted by Mr. Stevenson have been already published in THE JOURNAL OF THE DEPARTMENT OF AGRICULTURE OF PORTO RICO, Vol. IV, No. 1, for July 1919, pages 42 and 44, to which the reader is referred for details. Taken as a whole, these analyses did not lead to any practical conclusion, as no definite tendency was

manifest, and the variations would occur in all possible directions, regardless of the pathological condition of the plant.

A plan for a series of systematic analyses of healthy and diseased canes, that would eliminate as far as possible the variations due to the different factors that would bear on the results, was prepared by this division, in coöperation with the director, and the results obtained and the conclusions drawn from them are now presented in this paper.

The experiments were all performed at Central Bayaney, at Hatillo, whose board of directors extended their heartiest coöperation for the work, and did not spare any effort to help in every way possible to the success of the experiment. If everywhere the same spirit were shown, it would certainly be a pleasure to pursue lines of investigation which demanded coöperation of outsiders and many an agricultural problem would be more easily, cheaply, and wisely solved. In passing, I wish to extend my sincere thanks to the directors of Central Bayaney, and especially to the superintendent, Mr. Manuel Gorbea Pla, whose interest in the work did so much to overcome difficulties and make the work possible.

The analyses were performed on two different occasions: in May, 1919, toward the end of the grinding season by the assistant chemist, Mr. Rafael Vilá Mayo, and in December of the same year at the opening of the 1920 campaign by the writer.

PLAN OF THE EXPERIMENT.

The plan of the experiment was very simple. The basic idea was to make comparative analyses of healthy canes and canes in different stages of the disease growing under the same conditions, and showing as little individual differences between them as possible. The idea of taking separate samples of canes in different stages of the disease was suggested by previous work done on samples received from Central Cambalache. While working with these samples the writer noticed that marked differences were shown by the analyses of healthy canes and canes whose leaves were mottled but whose stalks were sound, on the one hand, and canes with cankered stalks on the other. Among the stalks which were cankered, some were badly cracked, and naturally, the idea suggested itself that the cracks in the stalks might be responsible for the differences observed. Accordingly, this point received due attention in the plan formulated. The following definite stages or manners of appearing of the disease were recognized: (1) canes whose leaves only were mot-

tled, but whose stalks were perfectly sound; (2) canes whose leaves were mottled and whose stalks were striped and slightly depressed near the joints; (3) canes whose leaves were mottled, and whose stalks were badly cankered but showed no cracks; and (4) canes whose leaves were mottled and whose stalks were both badly cankered and cracked.

In Mr. Vilá's work two series of analyses were made. In the first, series A, parallel analyses were made of healthy cane, cane showing the mottling in the leaves only and canes with stalks badly cankered, but not cracked. For these analyses Rayada cane was exclusively used. In the second, series B, the comparison was made between healthy cane, cane with mottled leaves only, and canes with stalks cankered and cracked. For this series Cavangerie cane was used, as not enough Rayada canes could be found with cracks in the stalks. The samples were taken in groups of three, each sample in the group consisting of five canes. All samples in a given group were taken from stools standing as close together as possible, using canes in different stages of the disease from the same stool whenever feasible. The individual canes were selected so as to have all the uniformity allowed by the circumstances as to age, development and maturity. Comparisons, therefore, should be made between the different samples in the same group, and not between samples belonging to different groups. Each group was marked with a number and the letter of the series.

In the December work performed by the writer, four series of analyses were run: series C, D, E, and F. In these instances only two stages of the disease, instead of three, were compared at a time. Accordingly, groups of two samples each were taken and again five canes were allowed to each sample. All the precautions observed in the cutting of samples in the two previous series were carefully followed in taking these. As in this case only two samples were required for each group, it was possible to obtain them from the same stool, or from two adjacent stools more often, thus affording more opportunity for uniformity in the cane selected. Besides, only one class of canes, Rayada, was used in all the series, thus eliminating the possible element of variation due to varietal characteristics.

Series C was carried out with healthy canes, and canes which had the leaves only mottled. However, in groups 6–C, 8–C and 10–C, some stalks on the diseased samples were very slightly affected. The symptoms of the disease in these stalks were so slight that they were not thought to affect the results materially, and were preferred

to others which were perfectly sound, for their close proximity to the corresponding healthy stalks in the groups. This cane came from a *plantilla* (plant cane) planting which was one of the most vigorous in the place.

The purpose of the next two series, D and E, was to compare healthy canes with canes having mottled leaves and stalks visibly affected, but not cracked, and to see whether there was any difference in behavior between plant cane and ratoons. Accordingly, series D was run with plant canes, which had normal development, and were doing very well, and series E was run with samples from a field of fifth ratoons. In both cases the diseased canes showed striped, wrinkled internodes, depressed near the joints, and leaves heavily mottled. It is interesting to observe here that canes were found which, although having stalks in the condition just described, did not show any mottling in the leaves. Such canes were not included in the samples taken.

Series F. In this series canes with mottled leaves and sound stalks were compared with canes with stalks cankered and cracked. Although a fifth ratoon, the plantation was producing larger canes and more cane than any other in the place. The stalks were large and fully developed, and the stools had twelve to eighteen or twenty canes each. The plants with sound stalks taken had their leaves very heavily mottled, and most of the plantation was in this condition. The affected stalks were profusely striped, with a number of cracks running along the lower half of the stalk. Some of the internodes were very much depressed, but others were only mottled and cracked. It was hard, however to find stalks in this condition as the percentage of canes affected in this way was very low.

The samples were brought to the laboratory and immediately analyzed. The juice was expressed in a handmill by passing the cane twice through the mill, which gave an extraction ranging from 51 to 60 per cent. The juices were strained through a copper wire strainer and the following determinations performed on them: degree brix, sucrose, acidity, reducing sugars.

METHODS OF ANALYSES.

Brix.—Was determined as usually with the common brix spindle, the temperature of the juice taken, and the correction for temperature introduced according to the table given by Spencer.

Sucrose.—Sucrose was determined by the single polarization method of Horne's, using dry lead subacetate for clarification. The

tables given by Spencer in the 1917 edition of his "Handbook for Cane-Sugar Manufacturers" were used for computing the sucrose from the polariscopic reading and the degree brix. The writer is aware of the fact that this method will not give the absolute per cent of sucrose in the juices, but it was thought to give sufficiently accurate results for comparative work.

Acidity.—It was intended to use logwood solution as indicator in the determination of acidity, but the reagent did not arrive in time for the spring work, so that Mr. Vilá had to use litmus instead. It was found, by previous tests, that more concordant results between duplicates could be obtained by using the paper rather than the extract. Ten cubic centimeters of the juice were taken, diluted with about 50 cc. of distilled water, and N/10 sodium hydroxide solution run in until neutralization, as shown by the permanence of color of two strips of litmus paper, one red and the other blue, dipped in the solution. However, by December we already had the desired logwood extract, and this indicator was used in the succeeding series of experiments. Again 10 cc. of the juice were diluted with 50 cc. of distilled water, so as to make more perceptible the change in color of the solution. This indicator was found to give very satisfactory results. As shown in the tables, the acidity has been expressed as cubic centimeters of N/10 alkali solution required to neutralize 100 cc. of juice.

Reducing sugars.—Under the limitations and lack of facilities in which this work was carried out the gravimetric method, which would have been preferred by the writer, could not be used. In looking for a volumetric method, accuracy and speed were the factors considered. The method had to be rapid enough to allow of a number of determinations being made by a single manipulator with very scant equipment, in a short time, as it was not desired to preserve juices for any length of time for this work. These determinations were to be made in fresh juice, as soon as possible after being expressed from the canes. Consider that only one alcohol lamp was available, and that consequently not more than one sample could be heated at a time. Duplicates were made of all determinations, and in some doubtful cases three and four determinations were made on a single sample.

Having all these conditions in mind the method of Schoorl de Haas was chosen. Accordingly, the following solutions and reagents were prepared:

1. *Copper sulphate solution.*—69.28 grams of chemically pure

copper sulphate crystals were dissolved in 1 liter of distilled water. This solution was standardized against N/10 sodium thiosulphate as explained below. The reducing sugar equivalent of this solution was then determined by carrying out a test exactly as described for the juices, except that a standard solution of reducing sugar prepared by inverting c. p. sucrose was used.

2. *Alkaline tartrate solution.*—Prepared by dissolving 346 grams of Rochelle salts and 100 grams of sodium of hydroxide per liter.

3. *Tenth normal sodium thiosulphate solution.*—A tenth normal solution of sodium thiosulphate was prepared, and titrated against a mixture of 5 cc. of the copper sulphate solution and 5 cc. of the alkaline tartrate after boiling for exactly two minutes and the addition of 20 cc. of 20 per cent potassium iodide sol., and 10 cc. of dilute sulphuric acid prepared as directed below. From this the equivalence of both solutions was found. All details given for the actual carrying out of the method with juices should be observed in this titration.

4. *Potassium iodide solution.*—A 20 per cent solution of potassium iodide solution was prepared.

5. *Dilute sulphuric acid.*—The solution was made by mixing equal volumes of chemically pure sulphuric acid sp. gr. 1.84 and distilled water.

Procedure.—Ten cubic centimeters of juice were diluted to a volume of 100 cc.

To ten cubic centimeters of the juice solution, 5 cc. of the copper sulphate solution and 5 cc. of the alkaline tartrate solution were added in an Erlenmeyer flask of about 300 cc. capacity. The flask was then quickly brought to boiling, and the boiling continued for exactly two minutes, at the end of which time the flask was suddenly brought under the tap and rapidly cooled to about 60° C. Twenty cubic centimeters of the 20 per cent potassium iodide solution were then added, and then 10 cc. of dilute sulphuric acid. The copper sulphate not reduced by the juice was then immediately titrated with N/10 thiosulphate solution using starch as indicator, to a very pale or almost white color. From the number of cubic centimeters of thiosulphate required for each cubic centimeter of copper sulphate solution as already determined, the volume of copper sulphate solution not reduced by the juice was calculated. This amount, subtracted from the 5 cc. of copper sulphate solution used, leaves the number of cubic centimeters of copper sulphate solution reduced by the juice. From the reducing sugar equivalent of the copper sulphate solution

the amount of reducing sugar in the 10 cc. of juice solution taken was found, and the percentage then calculated.

RESULTS AND CONCLUSIONS.

The results are presented below in tabular form and in graphs plotted from the data given in each table, so that for each table there is a corresponding graph.

In plotting the curves only the data for sucrose, acidity and reducing sugars have been made use of, as these are the real dominant factors, and the inclusion of the degree brix and the purity would contribute nothing in this instance toward reaching a conclusion, while introducing more or less confusion in the diagrams.

As the purpose is to compare the condition of the samples in each group with one another rather than to compare results between different groups, the numbers of the groups were taken for abscisae and the percentage of sucrose and invert sugar, and the acidity expressed in cubic centimeters of N/10 caustic soda per 100 cc. of juice, for ordinates. It is clear, then, that there is no relation to be expected or found between ordinates and abscisae, and that the diagrams only purpose to show the comparison between the samples in each group irrespective of the other groups, by means of the relative positions of the corresponding points in each group. In other words, the results obtained for all samples in a given group appear represented by points in the same vertical line, and that line is marked at its foot on the horizontal designated "Base line" with the number corresponding to the given group. The points were placed by counting up from the base line the number of centimeters corresponding to the percentage which they intended to represent according to the scale given in each diagram for each group of lines. The points by themselves, then, would have been sufficient, but they have been connected by lines as a help to the eye and to the imagination in establishing comparisons between the different positions.

Special attention should be called to the graphs plotted from Table II. Here some points appear which have not been connected by lines. The explanation is as follows: In groups 4 and 6 the samples corresponding to the mottled canes, and in group 5 the samples corresponding to the healthy cane, were lost, so that no figures appear for these in the table. No points appear in the graph for these corresponding positions. This left isolated the points corresponding to the samples of mottled cane in positions 5 and 7, and they are shown by points surrounded by circles of red broken lines

It will be noticed that, for the sake of contrast, the points on black lines are indicated by red circles, and the points in red lines by black circles. Where two concentric rings are seen as in the acidity curves at positions 1 and 2, it means that the points belonging to two different samples coincided. In these instances the acidity of the healthy and the mottled canes was exactly the same.

The horizontal straight lines mark the levels for the averages in each set of samples of canes affected to the same extent by the disease.

TABLE I—SERIES A.

COMPARATIVE ANALYSES OF HEALTHY CANES, CANES WITH THE LEAVES MOTTLETD AND SOUND STALKS, AND CANES WITH LEAVES MOTLED AND STALKS AFFECTED, BUT NOT CRACKED.

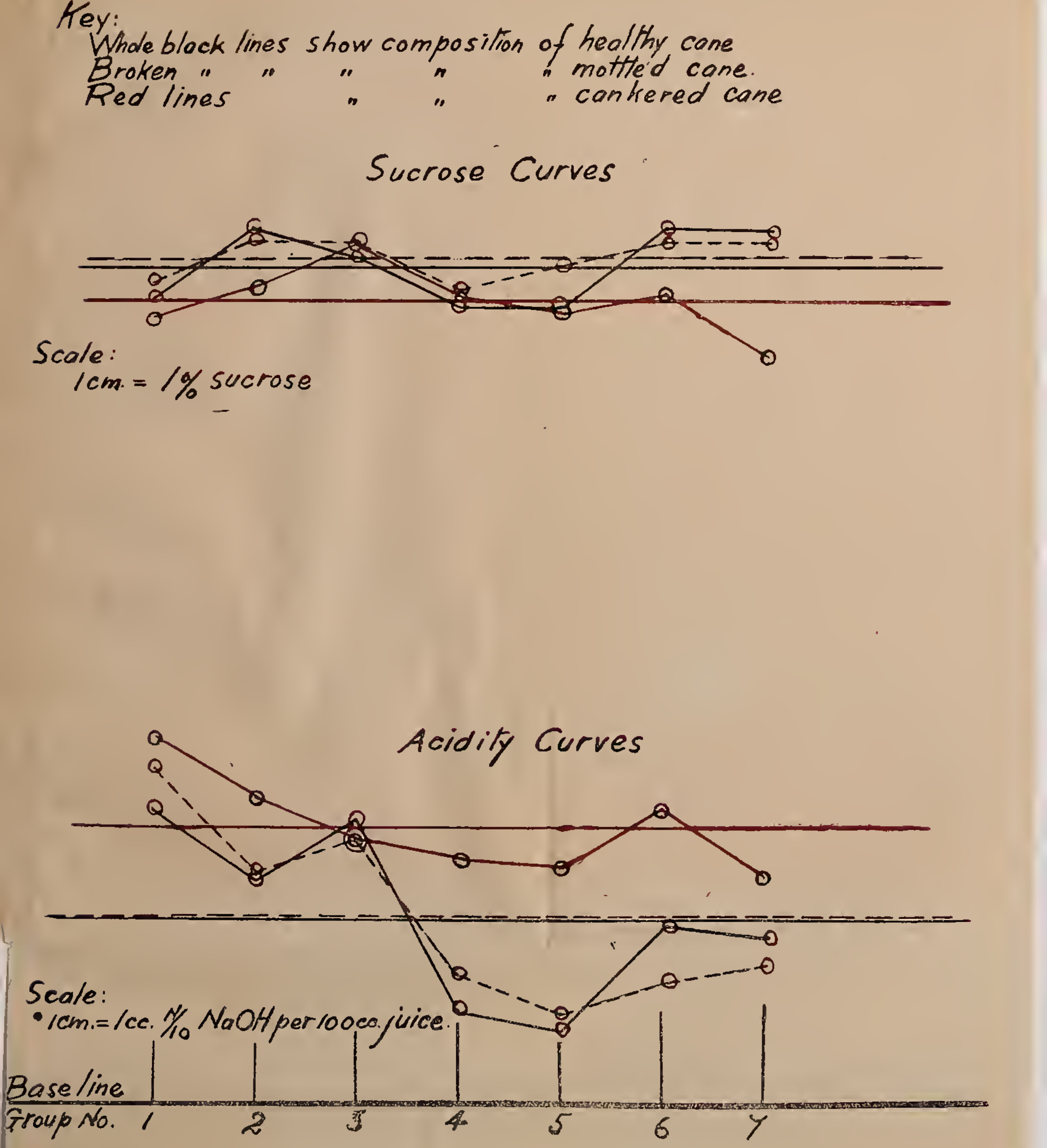
The different stages are distinguished in the table below by the terms "healthy," "mottled," and "cankered," respectively.

RAYADA—MAY 3 TO 10, 1919.

Group No.	Brix			Sucrose			Purity			Acidity. Cubic cent. N/10 NaOH per 100 cc. Juice		
	Healthy	Mottled	Cankered	Healthy	Mottled	Cankered	Healthy	Mottled	Cankered	Healthy	Mottled	Cankered
1—A	19.00	18.80	18.60	15.70	16.00	15.30	81.60	85.10	82.26	5.80cc.	6.60cc.	7.20cc.
2—A	18.80	18.70	18.30	17.00	16.83	15.90	90.42	90.00	86.89	4.40	4.60cc.	6.00cc.
3—A	18.20	18.60	18.40	16.50	16.78	16.70	90.66	90.10	90.79	5.60cc.	5.20cc.	5.20cc.
4—A	17.20	17.60	17.00	15.51	15.90	15.70	90.17	90.34	92.94	1.80cc.	2.60cc.	4.80cc.
5—A	17.40	17.70	17.10	15.50	16.30	15.40	89.08	92.09	90.05	1.40cc.	1.80cc	4.60cc.
6—A	19.30	18.60	18.50	17.03	16.77	15.70	88.20	90.20	84.90	3.50cc.	2.40cc.	5.80cc.
7—A	18.40	18.60	16.90	17.00	16.76	14.55	92.40	90.10	86.10	3.30cc.	2.70cc.	4.50cc.
Averages	18.328	18.371	17.828	16.32	16.477	15.607	89.044	89.690	87.542	3.685cc.	3.700cc.	5.442cc.

On closely examining Table I, we find that by comparing the analyses of the different samples in the same group we do not discover any great discrepancies as regards the degree brix, the sucrose content and the purity of the juice. Out of seven groups analyzed in only four instances is there a decrease in the sucrose content of the cankered canes as compared with healthy canes, and in only three instances is the purity lower in the cankered than in the healthy canes. In only one instance is there a considerable difference in favor of the healthy canes, in group 7–A, in which the difference in sucrose reaches 2.45 per cent, and the purity is 6.3 points lower in the cankered cane. But this seems to be a case in which individual variations affected heavily the analysis of the sample, as it is the

Curves Plotted from Data in Table I



only instance in which such discrepancies are manifested. In two other cases only is the sucrose content of the cankered cane lower than that of the healthy cane by as much as 1 per cent. These are in groups 2 and 6. Turning now to the averages, we find both sucrose and purity lower in the cankered canes, but if the exceptional instance of group No. 7 is left out, these differences become too small to deserve consideration. Thus, averaging only the degree brix and the sucrose of the first six groups of cankered canes, and finding from the averages obtained the resulting purity, we get 17.983 for the brix, 15.783 for sucrose and 87.771 for purity. These will produce the differences of only 0.563 in sucrose and 1.273 in purity when compared with the averages of the samples of healthy canes.

An inspection of the sucrose curves constructed with these figures show these points very clearly. It will be noticed that only the extreme point to the right of the red curve falls at a considerable distance below the corresponding point in the whole black line, and that only in two other cases at positions 2 and 6 show the corresponding points a noticeable difference in levels. In other cases the points in the red line are either a very short distance below, or slightly above those in the curve for healthy cane. It should be remembered that a distance of 1 mm. in the diagram shows a difference of only 0.1 per cent sucrose. The lines of averages, however, show a tendency toward a decrease on the part of the diseased cane, as mentioned in the discussion of the table. The conclusion seems warranted that the cankering of the stalk affects very little the sucrose content of the juice of diseased canes; or at least, that the extent to which it is affected would not be noticeable under factory conditions.

As for the cane having the leaves only mottled, a mere glance at the figures is enough to show that there is no difference between their juice and that of healthy canes. If anything, they seem to show up slightly better than the healty ones.

This is very well shown by the graph. As seen, the points in the curve for mottled cane appear in four instances above those in the same vertical line for healthy cane, while in the other three cases the points for the mottled are only very slightly below those for healthy cane in the same group. This shows no more variation than could be expected if duplicate samples of healthy canes only had been analysed. Notice that the line of averages for the mottled cane reaches a higher level than that for healthy cane, but that the dif-

ference in levels is very little. It might as well have fallen below by about the same distance, for all we know.

With regard to acidity, the averages show that there is no difference between healthy and mottled cane, but cankered canes show a higher content, the excess being on the average equal to 1.757 cc. of N/10 caustic soda per 100 cc. of juice equivalent to 0.007028 gms. caustic soda in 100 cc. of juice. The curves for acidity as plotted from this table hardly need any comment. The coincidence of the two lines of averages corresponding to healthy and mottled cane as well as the relative positions of the corresponding points in the curves for these two classes of cane speak for themselves. The levels attained by the points in the curve for cankered cane as well as the line representing the average content show the greater acidity contained by these canes.

TABLE II—SERIES B.

COMPARATIVE ANALYSES OF HEALTHY CANES, CANES WITH LEAVES MOTTLED AND SOUND STALKS, AND CANES WITH CANKERED, CRACKED STALKS.

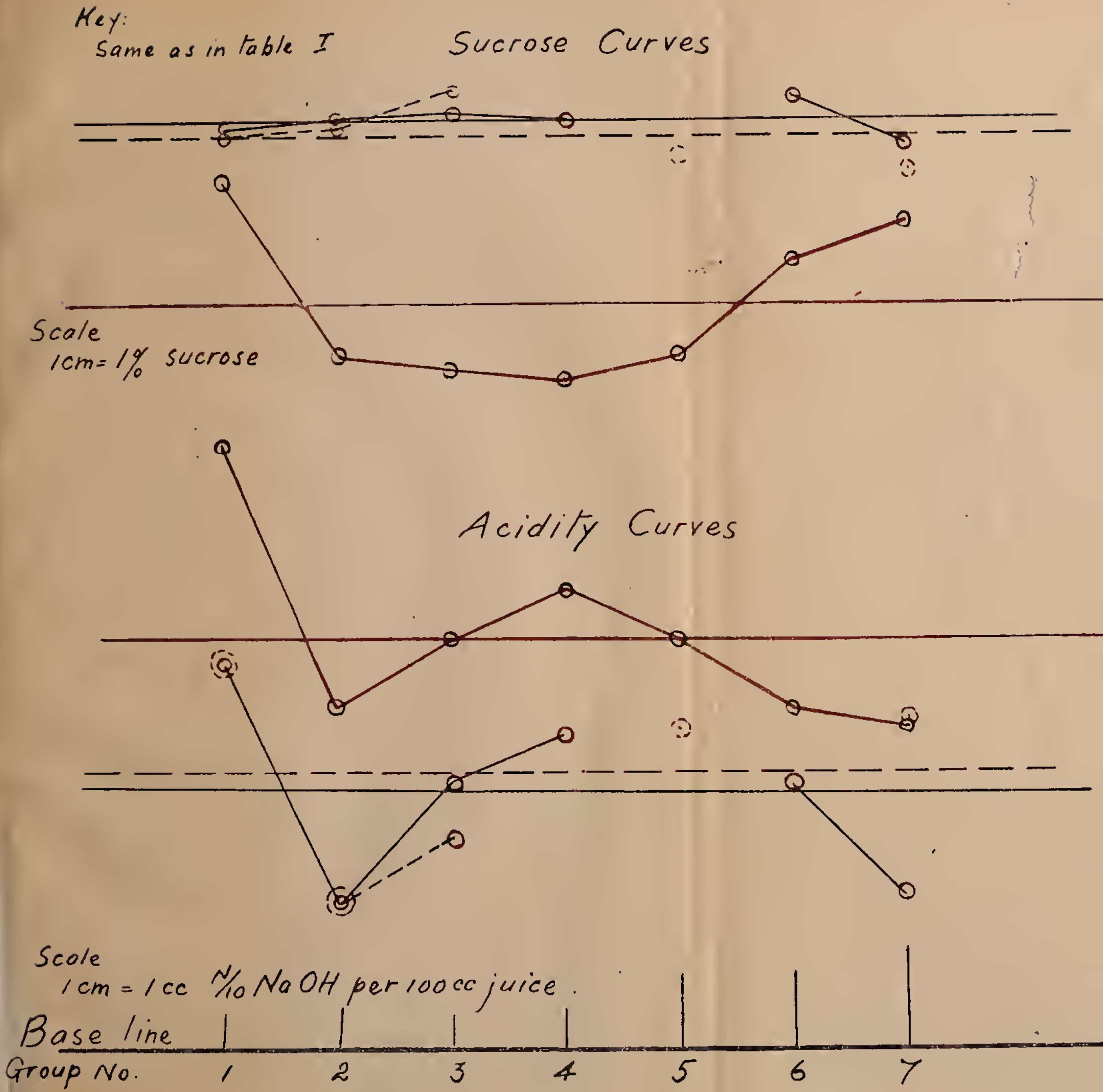
The different stages are distinguished in the table below by the terms "healthy," "mottled," and "cankered," respectively.

CAVANGERIE—MAY 3 TO 10, 1919.

Group No.	Brix			Sucrose			Purity			Acidity. Cubic cent. N/10 NaOH per 100 cc. Juice		
	Healthy	Mottled	Cankered	Healthy	Mottled	Cankered	Healthy	Mottled	Cankered	Healthy	Mottled	Cankered
1—B	18.00	17.90	18.00	16.16	16.00	15.25	89.80	89.38	84.72	6.80cc.	6.80cc.	10.60cc.
2—B	18.00	17.40	14.90	16.28	16.10	12.15	90.44	92.52	81.54	2.60cc.	2.60cc.	6.00cc.
3—B	18.20	18.20	15.50	16.40	16.78	11.90	90.40	92.17	76.77	4.80cc.	3.70cc.	7.20cc.
4—B	18.40	......	15.40	16.36	.....	11.75	88.96	.....	76.30	5.60cc.	....	8.10cc.
5—B	......	17.10	16.10	......	15.70	12.15	.....	91.81	75.46	....	5.60cc.	7.20cc.
6—B	18.80	......	16.60	16.74	.....	13.85	89.00	......	83.43	4.70cc.	....	6.00cc.
7—B	17.70	18.40	17.00	15.92	15.48	14.44	90.00	84.13	85.00	2.80cc.	5.80cc.	5.70cc.
Averages	18.183	17.80	16.214	16.31	16.012	13.07	89.699	89.955	80.609	4.55cc.	4.90cc.	7.257cc.

Looking now at Table No. II, we find a very different state of affairs as regards the composition of the juices of cankered canes as compared with the juices of healthy canes. Here the difference is apparent at first sight. The degree brix, sucrose content, and purity, appear consistently lower in the cankered canes. In groups 2–B and 4–B the difference in sucrose reaches over 4 points, being 4.61 in the latter, while the average of all the differences is as high as 3.066 points. Taking the difference between the two sucrose averages

Curves Plotted from Data in Table II



(average for healthy cane, and average for cankered cane), we obtain a difference of 3.24 points in favor of the healthy cane. In purity we find differences as high as 12 and 13 points in groups 3–B and 4–B, the lowest difference being of 5 points, in group 7–B. Comparing the averages, we find a difference of 9.090 between the purity and healthy cane and that of cankered cane. The figures for the mottled cane again fail to show any appreciable differences with the healthy cane as regards sucrose and purity.

A slight gain in acidity is evidenced by the average of mottled canes compared with that of healthy canes, but as no consistency in the differences shown by the samples in the individual groups is apparent, no conclusion should be based on this fact. There is no question as to the higher acid content of the cankered canes. It should be noticed that the acidity in these canes is higher than that shown by the cankered canes in the previous series. Altough for reasons that could not be controlled at the moment a determination of reducing sugars could not be made in every case, yet those that were made consistently showed that considerable inversion occurred in the juices of canes whose stalks presented fissures as a result of the disease.

Notice now the curves plotted from the data in this table, (Table No. II). The sucrose and acidity curves for healthy and mottled cane follow pretty close one another and the differences between their lines of averages are not of much consequence. The fact that relative positions of the lines of average for sucrose (as *regards healthy and "mottled" cane*) are in this case the inverse of what they are in the previous graph, further justify our conclusion that the mere mottling of the leaves do not seem to affect the sucrose content of cane to any appreciable extent.

The curves for the cankered cane with cracked stalks, however, strikingly show the lower sugar content and higher acidity in these canes. It is well to notice that with the exception of the points in positions 1 and 2, the points in the acidity curve attain higher levels and these in the sucrose curve appear at lower levels simultaneously, thus showing a corresponding decrease in sucrose whenever an increase in acidity is present. This correspondence will be further evidenced in the diagrams that follow. It is plain that this has been a clear case of fermentation due to the cracks in the rind of the cane.

The conclusion is irresistible that the cracking of the stalks causes inversion in the juices, with the consequent loss of sucrose. The higher acid content in these canes point to fermentation as the cause of this inversion.

Reasoning from the results obtained in these series of analyses, the conclusion should be reached that the disease in itself does not affect to any appreciable extent the sucrose content in the juice, and that it is only when the stalks are cracked and fermentation ensues that a considerable decrease in the sucrose content results, as it would result in any other case in which a cane had sustained mechanical injury enough to cause the exposure of its inner tissues. At an advanced stage, the disease, however, seems to induce of itself an acid condition of the juice, but not to any considerable extent.

We shall see whether this thesis is sustained by the results obtained in the experiments that follow.

TABLE III—SERIES C.

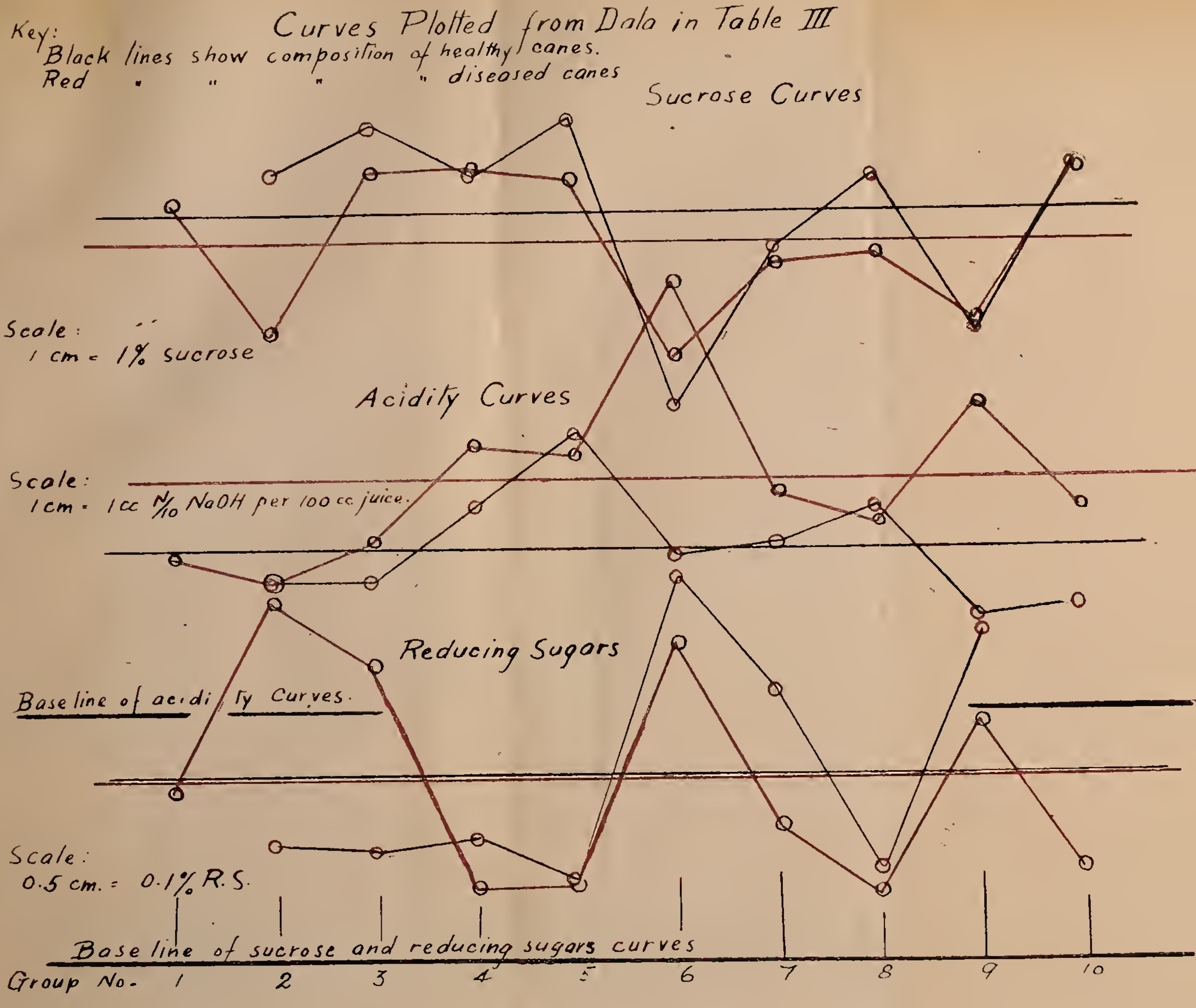
COMPARATIVE ANALYSES OF HEALTHY AND MOTTLED CANES.

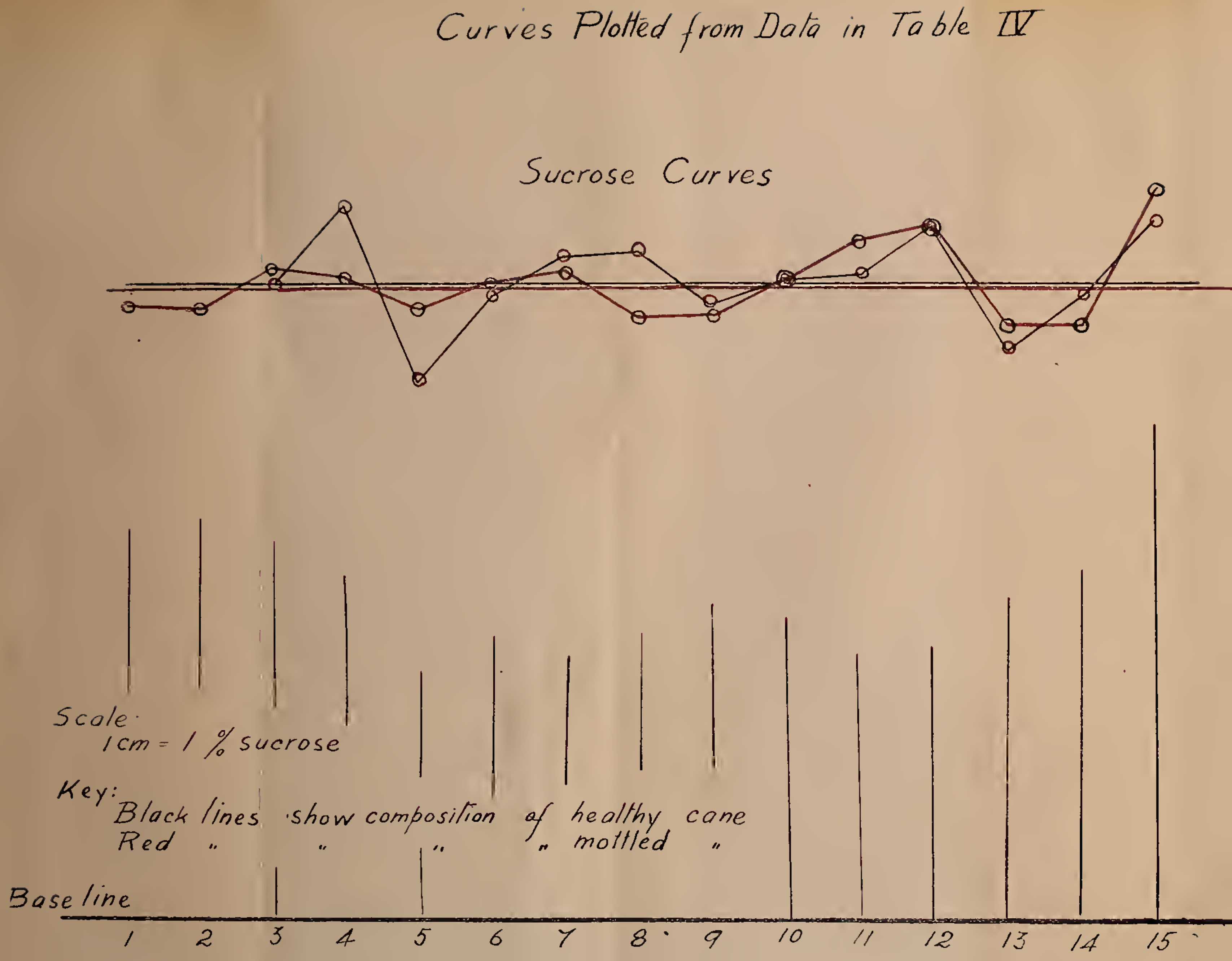
The diseased canes had only the leaves mottled.

PLANT CANE—DECEMBER 9, 1919.

Group No.	Brix		Sucrose		Purity		Cu. Cent. of n/10 Na OH per 100 cc. Juicce		Reducing Sugars	
	Healthy	Diseased	Healthy	Diseased	Healthy	Diseased	Healthy	Diseased	Healthy	Diseased
1—C............	....	16.73	....	15.13	....	90.43	....	3.00	....	0.674%
2—C	17.47	15.31	15.71	12.43	89.92	81.18	2.50	2.50	0.474	1.444%
3—C............	17.39	17.20	16.65	15.71	95.74	91.36	2.50	3.25	0.428	1.180%
4—C...	16.87	17.29	15.67	15.90	92.88	91.96	4.00	5.25	0.487	0.284%
5—C............	17.83	16.73	16.80	15.52	91.22	92.76	5.50	5.00	0.323	0.291%
6—C.......	14.59	15.23	11.00	11.94	75 39	78.39	3.00	8.50	1.549	1.251%
7—C............	16.66	15.99	14.12	13.85	84.75	86.61	3.25	4.25	1.067	0.532%
8—C............	17.16	16.26	15.62	14.04	91.02	86.34	4.00	3.75	0.352	0.261%
9—C	15.73	15.76	12.52	12.57	79.59	79.76	1.75	6.12	1.131	0.942%
0—C............	17.56	17.56	15.82	15.80	90.09	89.97	2.00	4.00	....	0.359%
Averages......	16.806	16.406	14.879	14.289	88.534	87.09	3.166	4.562	0.726	0.722%

An inspection of Table III will reveal the fact that no constant difference is introduced in the sugar content of the juices by canes attacked with the disease in which *only the leaves* have become mottled. The differences between the samples in each individual group point sometimes one way and then another, while the averages come as close to each other as could be expected under the circumstances. Slight differences in averages, cannot be taken, of course, as the guiding principle in a work of this nature. It is only a reasonably consistent series of differences all pointing the same way what should be taken as an indication of a cause uniformly acting to produce a given effect.


Curves Plotted from Data in Table III
Key:
Black lines show composition of healthy canes.
Red " " " " diseased canes
Sucrose Curves
Scale:
1 cm = 1% sucrose
Acidity Curves
Scale:
1 cm = 1 cc N/10 NaOH per 100 cc. juice.
Reducing Sugars
Base line of acidity curves.
Scale:
0.5 cm. = 0.1% R.S.
Base line of sucrose and reducing sugars curves
Group No. 1 2 3 4 5 6 7 8 9 10


Curves Plotted from Data in Table IV
Sucrose Curves
Scale:
1cm = 1 % sucrose
Key:
Black lines show composition of healthy cane
Red " " " " mottled "
Base line
1
2
3
4
5
6
7
8
9
10
11
12
13
14
15

A study of the curves plotted from the data presented in this table will reveal very interesting points. Although judging from the lines of averages for reducing sugars there is no difference as between the healthy and diseased canes, and while only a small difference in favor of the healthy cane is shown by the sucrose curves, yet there is shown a higher acid content by the diseased canes. This increase in acidity is constant throughout all the series in which this factor has been included. It is further to be noticed here, as well as further on, that this difference, though constant, is very small in all cases except in very acute stages of the disease, reaching its maximum development only when the stalks crack. But this point may be better discussed after all the other tables and curves have been examined. For the present it is enough to notice that the extra acidity induced is not enough to cause inversion, as shown by the coindicence of the lines of averages for reducing sugar.

Table IV and V show comparisons of healthy canes with canes which had mottled leaves and stalks depressed near the joints, but which showed no cracks or fissures in the stalks. In the first, plant cane was used, while in the second, ratoons were chosen. Both point to the same conclusion.

TABLE IV—SERIES D.

COMPARATIVE ANALYSES OF MOTTLED AND HEALTHY CANES.

The diseased canes in this series had the leaves mottled and the stalks affected but not cracked.

PLANT CANE—DECEMBER 17 TO 18, 1919.

Group No.	Brix		Sucrose		Purity	
	Healthy	Mottled	Healthy	Mottled	Healthy	Mottled
1–D	(X)	15.16	....	12.56	....	82.84
2–D	(X)	15.49	....	12.52	....	80.82
3–D	16.03	16.03	12.96	13.21	80.84	82.41
4–D	17.19	15.89	14.58	12.96	84.81	81.56
5–D	14.73	14.86	10.85	12.42	73.66	83.58
6–D	15.86	16.03	12.79	12.99	80.64	81.03
7–D	16.39	15.86	13.46	13.26	82.12	83.60
8–D	16.49	16.39	13.56	12.33	82.23	75.22
9–D	15.93	15.43	12.49	12.28	78.38	79.56
10–D	16.33	15.93	12.99	12.99	79.54	81.54
11–D	16.19	16.56	13.11	13.84	80.79	83.57
12–D	17.26	16.59	14.01	14.10	81.17	84.99
13–D	14.96	14.96	11.51	12.10	76.93	80.88
14–D	15.59	14.96	12.71	12.10	81.52	80.88
15–D	16.79	17.19	14.34	14.96	85.00	87.02
Averages	16.134	15.822	13.027	12.914	80.742	81.620

In Table IV, out of 13 instances in which a comparison could be established in only 5 cases did the diseased cane show a lower sucrose

content, and in only three cases was the purity of the diseased cane juices less than that of the healthy ones. The highest difference in sucrose in favor of the healthy canes was 1.62 points in group 4–D, in three other cases, groups 7–D, 8–D and 9–D, the difference was only of 0.20 to 0.23 points, and in group 14–D, of 0.61. In the three cases of lower purities, the differences were 7.01 points in group 8–D, 3.35 points in group 4–D, and 0.64 points in group 14–D. In 10 instances out of 15, and in 12 out of 15, the sucrose content and purity were respectively higher in the diseased canes. These considerations more than counterbalance the slight differences shown in the averages in favor of the healthy cane.

In Table V, the averages for the diseased and healthy canes show a wonderful agreement considering the circumstances. These figures hardly need any discussion; they speak clearly for themselves. There are no constant differences to speak of among the samples in each group or between the total averages obtained. Only in the case of the acidity seems there to be a tendency to show a slight constant difference pointing to an increase in the diseased canes. The differences, however, are very small.

Table V—Series E.

COMPARATIVE ANALYSES OF MOTTLED AND HEALTHY CANES.

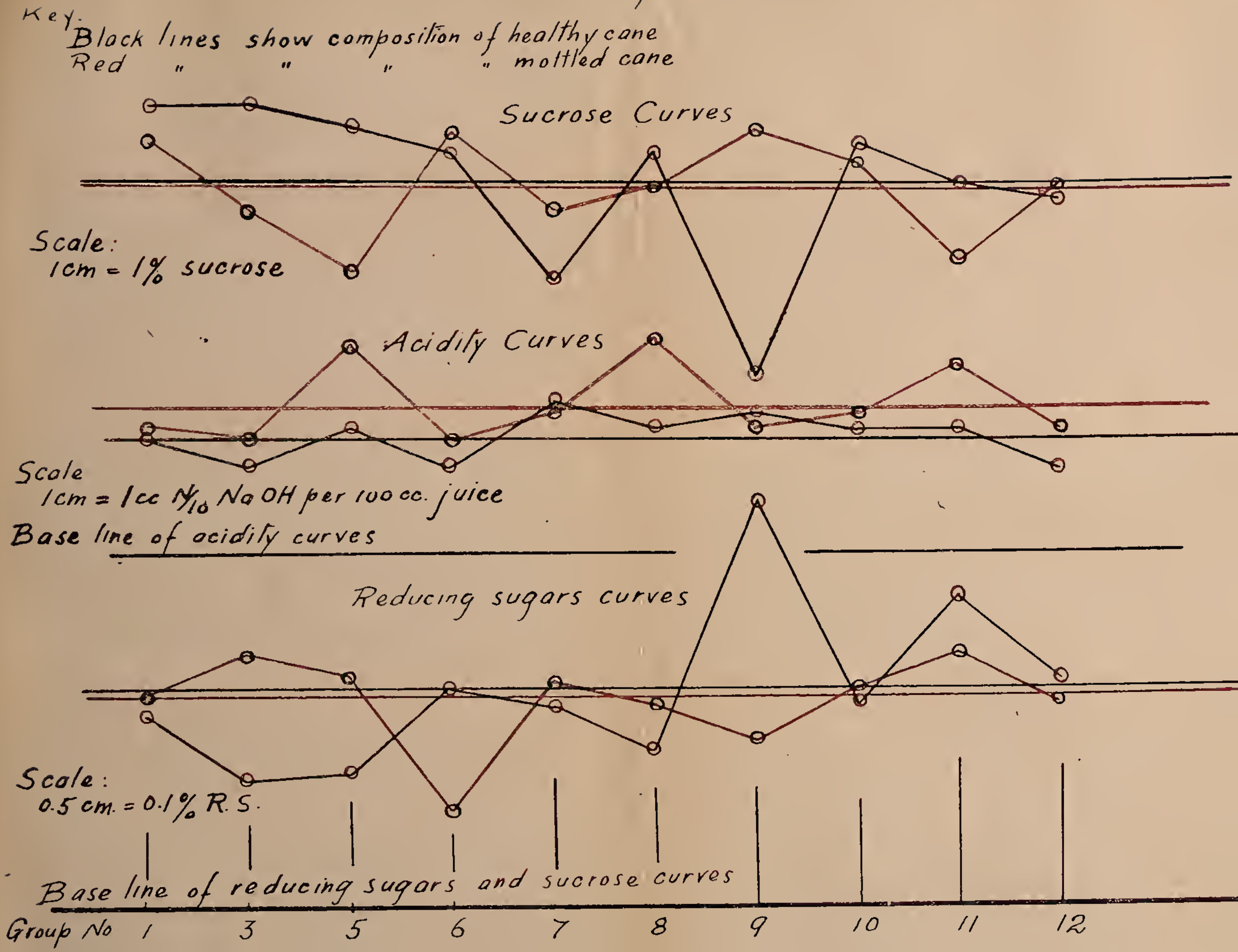
The diseased canes had their leaves mottled and the stalks affected but not cracked.

RATOONS—DECEMBER 20 TO 22, 1919.

Group No.	Brix		Sucrose		Purity		Acidity		Reducing Sugars	
	Healthy	Mottled	Healthy	Mottled	Healthy	Mottled	Healthy	Mottled	Healthy	Mottled
1–E	17.89	17.49	15.85	15.15	88.59	86.62	2.25cc	2.50cc	0.766%	0.856%
3–E	17.69	14.36	15.90	13.75	89.88	95.75	1.75cc	2.25cc	0.517%	1.037%
5–E	17.19	15.29	15.42	12.52	89.70	81.88	2.50cc	4.10cc	0.[illegible]32%	0.920%
6–E	17.26	17.29	14.90	15.32	86.32	88.60	1.75cc	2.25cc	0.872%	0.384%
7–E	15 06	16.56	12.40	13.81	82.33	83.39	3.00cc	2.75cc	0.805%	0.904%
8–E	16.79	16.84	14.98	14.22	89.22	84.44	2.50cc	4.25cc	0.637%	0.814%
9–E	13.56	17.39	10.50	15.36	77.43	88.32	2.75cc	2.50cc	1.625%	0.679%
10 E	16.96	17.26	15.15	14.79	89.32	85.68	2.50cc	2.75cc	0.814%	0.880%
11–E	17.06	15.56	14.32	12.79	83.93	82.19	2.50cc	3.75cc	1.243%	1.079%
12–E	16.29	16.53	14.02	14.23	86.06	86.08	1.75cc	2.50cc	0.901%	0.830%
Averages	16.575	16.457	14.344	14.194	86.539	86.249	2.325cc	2.960cc	0.8712	0.8383

These facts are more forcefully presented by the graphs corresponding to these tables. The sucrose curves plotted from Table IV

Curves Plotted from Data in Table V



continually overlap, thus showing normal differences, as should be expected in different samples even of canes carefully selected to eliminate individual variations. There is not shown, or even suggested, a preponderance on the part of any of the sets of samples upon the other. The slight differences between the levels of the lines of averages in favor of the healthy cane cannot serve as the basis of a conclusion, in view of the lack of uniformity in the variations in the individual groups. The same comments apply with equal force to the sucrose and reducing sugar curves in Diagram V. Discussing further the curves plotted from Table V, we find again the increased acidity present in the diseased canes, in spite of the fact that the average for reducing sugars in these canes is slightly lower. Again this offers the suggestion that the slight increase in acidity has not been enough to cause inversion.

It should be noticed here as well as in the curves constructed from Table III that in fully 50 per cent of the cases compared the curves show an equal or lower glucose ratio for the diseased canes, a proof that the increase in acidity has not been enough to produce inversion. This may be seen by comparing the positions of corresponding points for sucrose and reducing sugars in each group of samples. Thus, in Graph III and referring to groups number 4, 6, 7 8 and 9 the distances from the base line to the points in the reducing sugar curve for diseased canes show a lower ratio to the distance from the base line to the points in the sucrose curve of these canes than the ratio shown by the distances indicated by the corresponding points in the curves for healthy cane. Remember that in only eight cases is this comparison possible as there were no reducing sugar determinations made in healthy cane groups 1 and 10. Refering now to Graph V and groups number 6, 7, 9 and 10, the ratios between the distances from the base line to the points in the red curve for reducing sugars and the distances from the base line to the corresponding points in the red line for sucrose is lower than the ratios shown by corresponding pairs of points on the black curves for reducing sugars and sucrose, while in groups number 11 and 12, these ratios are practically the same.

The two tables show rather conclusively that whether you take plant canes or ratoons the juice of the canes remain practically unaffected by the disease, (except for a slight increase in acidity noticeable in the juice of diseased canes), even when the stalks have become affected, provided that they preserve their rind whole, and no cracks have been formed.

TABLE VI—SERIES F.

COMPARATIVE ANALYSES OF CANES IN AN ADVANCED STAGE OF THE MOTTLING DISEASE AND OF CANES SHOWING ONLY THE FIRST SYMPTOMS.

In the former the stalks were badly cankered, showing cracks at intervals, while in the latter only the leaves were mottled, the stalks being in good condition. In the following the terms "cankered" and "mottled only" will be used to distinguish between them. No glucose determinations were made for lack of reagents.

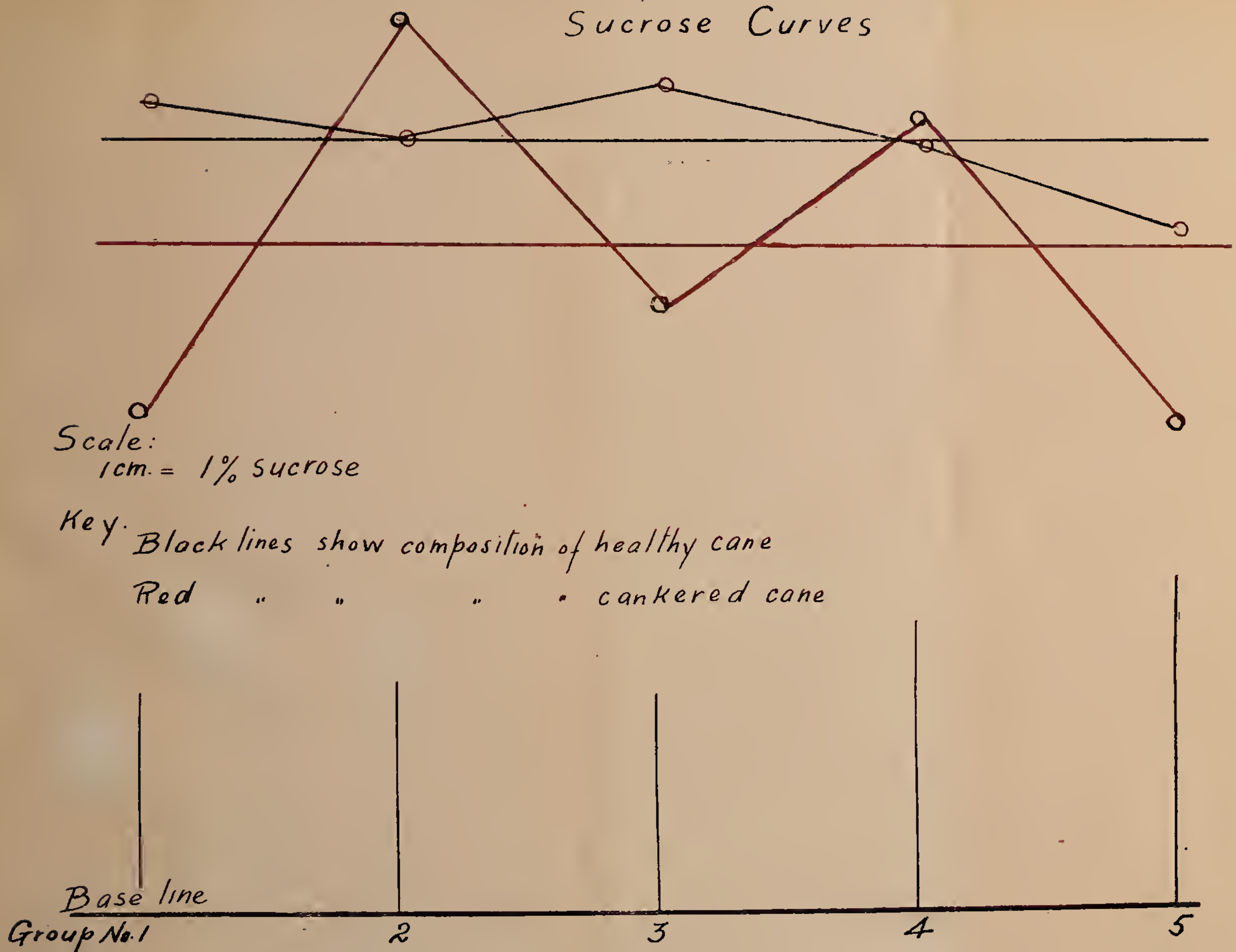
RATOONS.

Group No.	Brix		Sucrose		Purity	
	Cankered	Mottled only	Cankered	Mottled only	Cankered	Mottled only
1—F	13.79	17.39	9.74	15.76	70.63	90.62
2—F	18.71	16.89	17.34	15.07	92.67	89.21
3—F	14.86	17.56	11.78	16.05	79.27	91.40
4—F	17.13	17.23	15.42	14.97	90.00	86.88
5—F	13.79	15.89	10 50	13.30	76.14	83.70
Averages	15.656	16.992	12.956	15.030	82.766	88.453

Table VI affords an opportunity of comparing diseased canes with fissures in their stalks, with mottled canes having sound stalks. The differences again stand out clearly showing the effect of the cracks. It should be observed that aside of the cracks and the stripes shown by the stalks, these canes were well developed, and that in some of the samples the cracks were more numerous than in others. This accounts for the good showing made by two of the samples. The averages, besides, show appreciable differences. It is to be regretted that more samples of this type could not be secured, but the time available for the work was short, and searching for the few scattered samples of this sort that could be obtained in the place proved to be a time-consuming operation.

The curves plotted to represent the variations shown by this table hardly need any more comment than what has been said in connection with the table itself. The difference between the lines of averages is enough to point out the direction in which the changes occur. In the samples where the number of cracks was noticeable the difference in sucrose is striking, as shown by points in positions 1, 3 and 5. The two points showing a high sucrose content serve as further proof of the conclusion reached, as they were the samples with only a small number of cracks.

Curves Plotted from Data in Table VI



The results, further more, corroborate those obtained by Mr. Vilá, and shown in Table II.

SUMMARY.

1. Parallel analyses of healthy cane, cane with mottled leaves, and canes with leaves mottled and stalks affected by the disease but not cracked, conducted during the spring of 1919, failed to show any difference in the sugar content of the canes compared. A slight gain in acidity was observed on the part of the cankered canes. The canes used were of the Rayada variety.

2. A second series of parallel analyses using Cavengerie cane and substituting canes with the stalks cracked for the cankered canes with the stalks whole revealed higher acidity, lower sucrose content, and in the cases where tests were made, a higher content of reducing sugars in the cankered, cracked canes. No differences that deserve mention were noticed on comparing the canes with mottled leaves with the healthy ones, except for a slight tendency toward a higher acid content shown by the former.

3. Comparisons between healthy canes and canes with leaves mottled but unaffected stalks conducted in December, 1919, did not show any constant differences in sucrose, or reducing sugars, but again the increased acid content of the mottled canes, though small was noticeable.

4. Comparative analyses of diseased canes having their stalks affected, but not cracked, with healthy canes, using both plant cane and ratoons performed in December, failed again to show any appreciable differences in their juice composition as regards sugar content; the acidity, however, showed a slight increase in the diseased cane.

5. A series of experiments conducted to compare diseased, cankered canes having the stalks cracked, with diseased canes having sound stalks showed lower sucrose content and lower purity in the former.

CONCLUSION.

The general conclusion is forced by the facts as revealed by these series of analyses that the mottling or yellow-stripe disease does not affect materially the sugar content of the juice of canes attacked with the disease, except in an indirect way, when the stalks become cracked as a result of the drying up of the stalk. In this case the

exposure of the inner tissues brings about fermentation, as in the case of any other mechanical injury received by the stalk bad enough to cause cracking of the rind, with the subsequent increase of acidity, inversion, and loss of sucrose. There is, however, a tendency on the part of diseased canes to show an increase in the acid content of the juices, but this increase is not serious enough to cause inversion, except in very acute stages of the disease, and after the stalks have become cracked as a result of being badly cankered.

INFECTION AND NATURE OF THE YELLOW STRIPE DISEASE OF CANE (MOSAIC, MOTTLING, ETC.)

By J. Matz.

INTRODUCTION.

In December, 1918, the writer began studies of this disease in Porto Rico. The following is a summary of experiments and histological studies made during a period of twelve months. Owing to the conflicting views among investigators regarding the nature of this disease there could not be obtained much guidance as to any one definite line of investigation to follow out, so that even previous experiments carried out by others had to be repeated in order to gain a clear path for any line of investigation.

In reviewing the literature on this disease it was found that although the disease has been recorded to have appeared in cane fields which were previously known to be free from any visible signs of it, yet there is hardly any records of exact observations of its transmissibility to known healthy plants. There is no doubt that a large part of the spread of the disease is due to the use of infected seed, but it is also an undeniable fact that new or secondary infections occur. This is supported by records of observations made in Porto Rico, Java, Hawaii and Cuba. It would be erroneous to assume that healthy cane showing new cases of yellow striping had in actuality the disease in such a dormant state as not to show its symptoms up to a period of several months or more. Tests as to dormancy were made, at the beginning of this work here, with seed pieces from cane which were in a not advanced stage of the disease. Portions of these canes were cut into pieces having one or two eyes each and placed in glass moist chambers for germination. The cane and glass chambers were sterilized to remove molds and bacteria. In forty-five trials, using cane from three different sources, not a single case was found where the symptoms of the disease were not observable in the unfolding leaves in the shoots of diseased seed. Diseased seed always produced diseased plants; in other words, if the disease is present in the cane it will show up at an early stage in

the leaves, by its characteristic symptoms. Further tests along this line were made by planting diseased seed pieces in sterilized and unsterilized soil, in pots. Here the results were the same only with a slightly higher accentuation of the symptoms in unsterilized soil due to the fact that the seed piece breaks down quicker by the aid of ferments and fungi which sometimes abound in such soils, thus aiding in the stunting and deterioration of the young buds. In the unsterilized soil the young shoots became, in addition to the yellow striping, speckled with a reddish tinge, and formed a shorter stem with the leaflets growing in more or less of whorls.

There is the possibility of the symptoms being so faint as to evade detection to the casual observer. The various symptoms of the disease on different varieties of cane have been described in previous publications, and it is plain that the disease can be recognized in all instances. However, the writer had under observation four plants in pots which showed only an occasional thin stripe of a darker green on a field of lighter green. These plants were kept up in good condition having applied to them a liberal amount of nitrate with frequent watering. The symptoms of yellow stripe always existed in these plants in the older canes but in a rather less pronounced form. The young shoots, however, which occassionally come up at the bases of these canes show the symptoms more distinctly. Other plants, diseased, and growing under the same condition close to the above show the disease very clearly and distinctly. On the other hand the same variety, Crystalina, is known to produce clearly distinct symptoms upon its becoming diseased in the field. The above four plants are kept for further observations. A degree of severity exists in the different fields and in individual cane plants. The severity of the disease depends, as has already been observed by others, on varietal resistence, length of time the disease is propagated in a given plant, and local conditions under which the cane is growing. In an infection experiment conducted in the greenhouse of the Insular Experiment Station, mention of which was made in last year's report, the "canker" stage was observed to have occurred in a cane in three months from the time when the first signs of the disease were noticed. This is contrary to views held by others, *i. e.*, that it takes a certain number of generations for the canker stage to arise. It was really the general unfavorable conditions for the growth of the plant, as it was grown for almost a year in a five-gallon tin can, that helped the canker stage to be shown up sooner.

INFECTION EXPERIMENTS.

I. Contact.

During the first part of this year experiments such as have been tried by others have been repeated in order to gain an intimate knowledge of the behavior of the disease. Healthy and diseased plants were planted together in the same pots; healthy and diseased seed pieces were split in half, and then a diseased half and a healthy half were fastened together and planted. There were no transmissions of the disease to the healthy plants. The healthy plant, though in contact with the diseased plant, has not contracted the disease. The healthy seed produced healthy shoots right alongside the diseased seed and shoots in the same pot. Healthy seed pieces were watered with water in which diseased cane was allowed to stay for some time. No infection occurred.

An experiment was made to find out if the disease could be transmitted through the roots. Diseased tissue was fastened onto the root eyes of healthy seed, so that the growing rootlet may come in contact with the cut surface of the diseased tissue. Eight of the healthy seed pieces germinated and the shoots were healthy. After four months in the pots two shoots of the healthy seed showed symptoms of yellow stripe. The experiment was repeated but gave negative results. The fact that the symptoms were belated in showing up would indicate that the two plants became infected through another source. There were diseased cane in the greenhouse.

Another experiment was made in the following manner: Healthy and diseased seed pieces were cut to contain three dormant buds each. The middle buds were carefully cut out with a sharp knife. Care was taken to make the cut at least one-half inch on all sides from the bud, in order to leave uninjured root eyes and some tissue for the growth of the bud. The buds from the healthy seed were then inserted in the diseased seed in the places of diseased buds and the buds of the diseased seed were inserted in the healthy seed. Practically all of the buds germinated and from the first no transfer of the disease was observed to have taken place either in the healthy seed with the diseased buds or in the healthy buds inserted in the diseased seed. The grafts thus made did not live long but the seed in which they were inserted developed sound shoots from their original two remaining buds. It was thought that by bringing in contact the cut ends of the vascular systems of diseased and healthy cane a transmission of the disease might take place. But no infection occurred in this experiment.

II. Juice.

Experiment 1.—On April 16, an experiment was made in the folowing manner: Five cane plants of about 8 months old, growing in five-gallon tin cans in the greenhouse of the Insular Experiment Station were examined and found free from any symptoms of yellow-stripe disease. Each of these plants consisted of one single stalk of about one inch in diameter and averaging about three feet in height. At the bases of each were one or more shoots of about six inches in height. These shoots also were free from yellow-stripe disease symptoms. The five stalks were cut back leaving stumps of about four inches above ground, the shoots were left as they were. Juice from a yellow-striped piece of cane was pressed out and injected, with a hypodermic needle, into the stumps near the surface of the ground. On April 28 typical symptoms of yellow stripe was observed in the lower parts and along the mid ribs of the central leaves of two shoots in two out of the five pots. At first only a few, larger, light green, narrow areas were noticed; later these light green areas spread all over the leaves and they became patterned with short alternating light-green and green stripes. In one of the two pots which showed infection on the 28th of April there were two shoots at the base of the old stalk but only one shoot showed infection on that date; however, about a week later the other shoot became infected. In three months the infected stalks have become more or less shrunken at the internodes and showed typical cases of the "canker" stage. The other three plants remained free from the disease throughout the experiment which lasted ten months. In this and later experiments the positions of the plants were noted and they were kept in the original places throughout.

The Position of Plants in Experiment 1.

	Plants inoculated April 16				
	No. 1	No. 2	No. 3	No. 4	No. 5
April 28...........	free	diseased	free	diseased	free

Experiment 2.—On May 1 a similar experiment was made in the same greenhouse with similar plants. Twenty plants were inoculated with juice from diseased cane and 20 were left uninoculated as checks On May 14 two of the inoculated plants showed the symptoms of the yellow stripe disease. These plants are marked "D" in the next table.

The positions of the pots in this experiment were thus:

Bench 1:										
Inoculated	1	2	3	4	5	6	7	8	9	10D
Check	1	2	3	4	5	6	7	8	9	10
Bench 2.										
Inoculated	1	2	3	4D	5	6	7	8	9	10
Check	1	2	3	4	5	6	7	8	9	10

Experiment 3.—On the same date as the last experiment 10 plants were cut back only a little above the growing point, 5 of these were inoculated in the cut surface of the top by injecting diseased juice with a hypodermic needle, and 5 were left as checks. All of these have remained free from the disease.

Experiment 4.—On May 2, 25 healthy stools about three months old were transplanted from the field to the greenhouse in pots. The plants were cut back as in the first two experiments and 8 of these were inoculated with diseased juice and tissue; that is, in addition to the injection of juice, pieces of diseased cane were forced into small holes in the stems. All 25 plants remained free up to October when one of the checks developed the yellow-stripe disease symptoms. It must be stated that the four plants which developed the disease in the first experiments were of a lot of cane which were more mature than the last 25 plants. In order to test this point 18 seed pieces of mature Crystalina cane were cut to one or two eyes, 12 of these were inoculated near the base of the bud, by boring a hole into the seed piece three-quarters inch deep and directly into it was pressed juice from diseased cane, and 6 were inoculated in the same way with healthy cane juice. All were planted in pots and placed in the greenhouse.

Experiment 6.—At the same time 35 Crystalina stools in a field that has just been cut were inoculated with juice in the stubble near the bases of sprouting buds. In both of these last two experiments not a single positive case developed. The plants in the pots were transplanted, after four months in the greenhouse, to an open field, and up to the present no signs of the disease have become visible.

NATURAL AND SECONDARY INFECTION.

Experiment 7.—During the time when the above experiments were made there has not come to the writer's notice a case of second-

ary infection in the greenhouse, nor were there any such cases reported previously. This was rather strange as secondary infections were being picked up every two or three weeks in the adjacent cane fields. The greenhouse was not "insect proof." In order to make sure that secondary infections do occur in known healthy cane, 48 seed pieces from three healthy and mature Crystalina canes were planted in pots and placed in the greenhouse. After two months from germination three of the 48 showed symptoms of yellow-stripe disease. However, these three plants, together with a number of others of the same lot, were on the ground instead of on a bench.

Experiment 8.—So another series of 50 seed of three healthy white Otaheita cane were planted in pots and all were placed on clean benches. In about three months from germination one of two shoots from two separate seed pieces in the same pot became distinctly diseased.

Experiment 9.—Ten cane stools having been cut back and transplanted from the field to pots in the greenhouse have been allowed to grow for four months. These showed no signs of yellow-stripe disease during that period. At the end of four months they were cut back and allowed to sprout again. One shoot began to show yellow-stripe disease in the unfolding leaves, and in two weeks the entire stool became diseasd.

Experiment 10.—On May 15 five healthy stools in five pots were inoculated with diseased juice in the stalks near the root crowns. Up to September no symptoms of yellow-stripe disease have developed. During the first part of September the plants were all cut back and allowed to sprout up again, and two plants began to show the yellow-stripe disease in the central unfolding leaves of their shoots. It is assumed that these were secondary infections. It is of interest to note the development of the disease in one of these pots.

The position of the row of pots on the bench was thus: 1 2 3 4 5.

Numbers 2 and 5 became diseased. No. 5 had two small *cepas* of 5 to 7 shoots. Both *cepas* came out from two original buds on the sides of a single seed piece. At first one *cepa* showed the disease, the symptoms of yellow stripe appearing first in one shoot and then in another until all became visibly infected. In about three weeks the second *cepa* became diseased, and again a gradual spread of the disease from one shoot to another was observed. In all of these shoots

the central leaves always showed the symptoms first. It appears that the disease gradually communicates from one shoot to another through a common channel.

It is quite certain from observations made on healthy and diseased plants grown in close contact with one another, that mere surface contact does not transfer the disease to healthy plants. In the greenhouse a row of 10 diseased plants were placed alongside of a row of 10 healthy plants, allowing for contact between the healthy and diseased leaves, and not a single case of new infection resulted. However, during the late part of the summer a healthy plant which was adjacent to a diseased one in the greenhouse became diseased. This is the first case of its kind in the greenhouse, its occurrence should rather be layed to an outside agent rather than to its being close to a diseased plant.

The occurrence of yellow stripe in the greenhouse has been in all features similar to the way it works in the field. It attacks the young shoots and it is sporadic in location, it picks out a plant here and there only and there is not a general spread taking in complete areas. In the field a new infection may sometimes be observed on large cane, but from personal and close watch of the plants in the greenhouse secondary infection on more or less grown cane has not been seen.

The following conclusions can be drawn from the above observations; first that healthy cane from healthy seed became infected with the yellow-stripe disease; and secondly that the disease has been transferred artificially to healthy plants in four cases at least. It should be observed that in both, Nos. 1 and 2 experiments, the disease showed up in about two weeks from inoculation and there were no other new infections in the other plants in the greenhouse at that time. However, the exact method to insure takes is not known as yet. The prevailing idea that insects are the carriers of this disease is highly plausible, but the writer has not taken up this phase of the problem.

HISTOLOGICAL STUDIES.

Histological studies of yellow-striped cane were made with the view to determine if possible in what way the disease affects the tissue of the host. A search for abnormalities in the interior of the cane stalk and leaves of diseased plants was made. Tissue from dis-

eased mature cane stalks, from underground parts, from growing points and from leaves were cut with a sharp razor free hand and with the microtome. In studying microscopic sections of the outer cankered tissues of yellow-striped cane it was noticed that sometimes the parenchyma as well as collenchyma cells of the discolored areas possess very distinct, single, spherical, darkly colored and dense protoplasmic bodies. At first glance these resemble spore bodies of some organism. (Fig. 1 *a, b.*) These bodies were also found in the centre of diseased cane. In searching in the tissues of non-yellow striped cane it was found that these bodies also exist in parenchyma cells there. It was found in the base of a young stalk which was

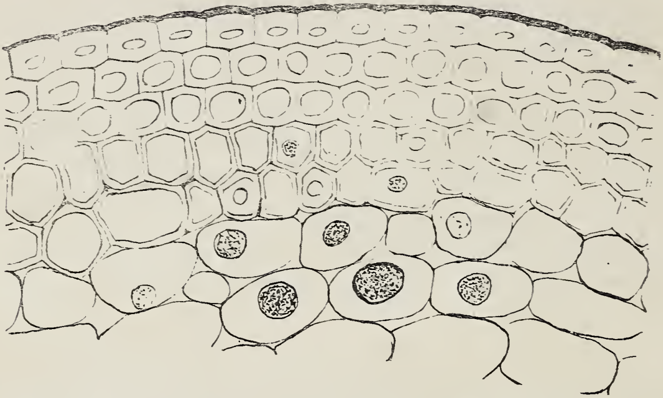


FIG. 1 *a.*—Dense and deeply colored nuclei in cane tissue near the rind. Drawing of a free-hand section from a yellow-stripe diseased stalk. (× 150.)

injured by a mechanical agent, it was found in the cells of roots of non-yellow striped cane and in the injured part of a stalk of cane of the same nature. It seems clear enough that under certain conditions of growth the nuclei of certain cells become dense and deeply colored and give the appearance of dense granulation when influenced by an inhibitory or injurious factor. Sections of tissue containing the spherical bodies refered to above could not be permanently mounted in the usual way as alcohol dissolves those bodies. When placing a free hand section in alcohol the spherical bodies become vacuolated and ultimately disappear from view, only a very thin wall being left.

Paraffin sections of the uppermost nodes of yellow-striped and healthy cane were made. It was observed that a difference in the appearance of their respective tissues existed (Figs. 2, 3, and 4).

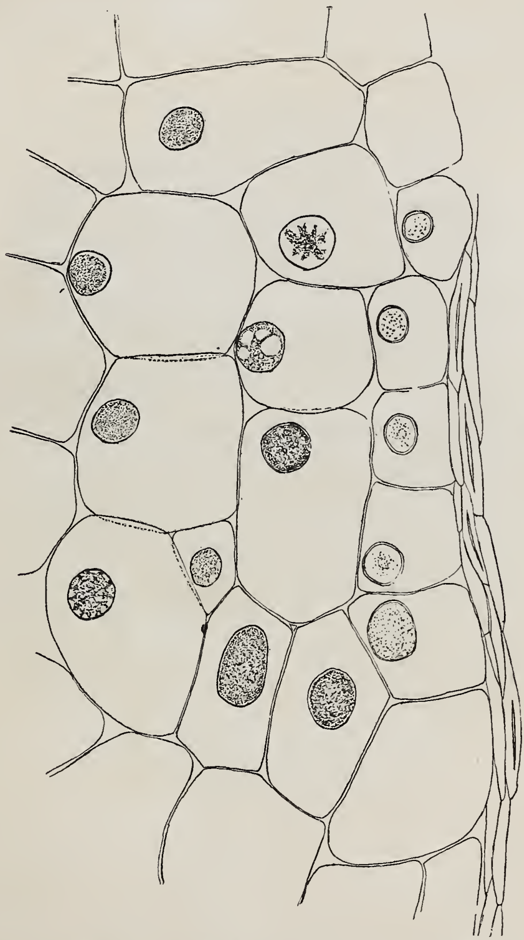


FIG. 1 *b*.—Drawing of similar bodies as in Fig. 1 *a*, in cells of non-yellow stripe but otherwise injured cane tissue. (× 250.)

In the diseased tissues some of the parenchyma cells between the fibro-vascular bundles were filled with a protoplasm which was dense and finely granulated, the bundles showed apparently the same sub-

stance in the sieve tubes and vessels,[1] while in the cells of the healthy cane the fibro-vascular bundles were free and the parenchyma between the bundles contained scattered and coarser granules. The last named are common in cut and exposed portions of young growing parts of cane.

Leaves of about the same age of healthy and yellow-striped cane were studied. Figures 5 and 6 show a striking difference in the appearance of the two. The healthy leaf in cross section shows no abnormality except slight shrinkage; in the diseased leaf some of

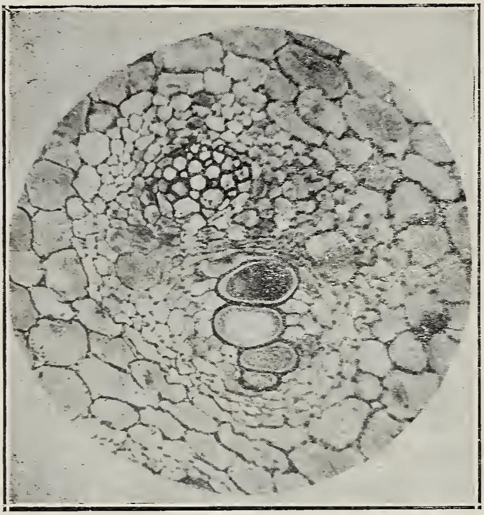


FIG. 2.—Photograph of a vascular bundle from near the growing point of yellow-stripe diseased cane, showing the finely granular substance in the vessels. (×50.)

the epidermal cells, especially near the stomata, and some internal cells show dense contents which is colored slightly brown, and which is similar in appearance to the abnormalities found in the cells of the cane stem. It seems that a foreign plasmodium-like substance is apparently present in the cells of the yellow-striped cane leaf and stem tissue.

[1] The writer has of late seen specimens of cane affected with gum disease due to *Bacterium vascularum*. This disease is distinctly different from the yellow-stripe disease, the gum of the former is yellow and full of bacteria which are easily cultured. No slimy exudation occurs in yellow-stripe disease.

Further research along this line revealed the presence of the above plasmic substance more constantly and in a more defined form in "cankered" cane stalks. In investigating the histology of "cankered" cane a feature, which has not been mentioned before in the literature on the subject, has been noticed. Cankers have been characterized as exterior symptoms consisting of a few outer layers of

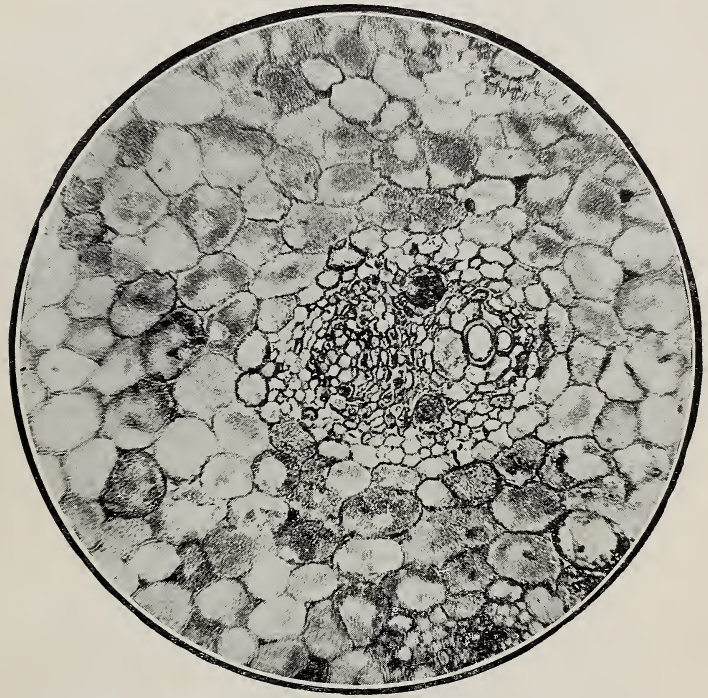


FIG. 3.—Photograph of a cross section through a growing point of yellow-stripe diseased cane. Note the character of the parenchyma cells and compare with Fig. 4.

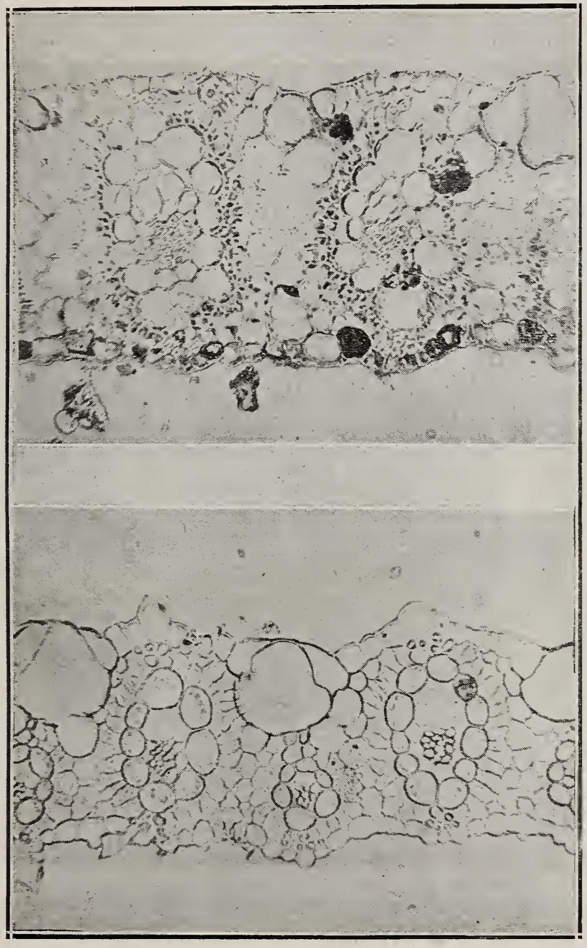
deteriorated cells, but in reality one may find separate and distinct pockets of brown to reddish-brown tissue deep in the interior throughout cankered cane. More often such a discolored region may be found in the form of a short streak, several centimeters in length, usually very close to the rind of the stalk, but these streaks are not always exposed as they are found even where no breaking of the outermost layers of cells has taken place. Together with these dis-

tinctly brownish-colored areas there may also be present in the interior of stalks small longitudinal and light-colored areas where the parenchyma cells have entirely collapsed and leaving an empty cavity of a millimeter or more in width and of variable length. Microscopic sections of the discolored areas in yellow-striped cane stalks show that some parenchyma cells are full of a more or less

FIG. 4.—Photograph of a cross section through a growing point of a healthy cane stalk. (× 50.)

hardened or compact, densely but finely granulated, and slightly browned plasma. (Fig. 7.) Usually there are small groups of a few cells thus filled, but it is not uncommon to find only a single cell (Fig. 8), full of the granular material while the surrounding cells only show a slight brownish discoloration in their walls. This phenomenon is common in older portions of more or less full-grown cankered cane, especially where an alteration in color exists in the

stem tissue. It has also been observed in leaf sheaths of yellow-stripe diseased cane. Here it is found in slightly depressed areas on the inner side of apparently uninjured leaf sheaths. It seems that the



FIGS. 5 AND 6.—Upper figure is a photograph of a cross section through a yellow-stripe diseased cane leaf. The lower figure is a photograph of a cross-section through a healthy cane leaf. ($\times$ 100.)

plugging of parenchyma cells in this manner is a diagnostic feature peculiar to yellow-stripe disease.

Free hand sections and sections from tissue which was fixed and

killed and imbedded in paraffine, from internal portions of cankered cane, were treated in the usual way, *i. e.*, dehydrated with alcohol and cleared with xylol. The cells which contained the dense and finely granulated substance did not lose it in the process of mounting.

FIG. 7.—Photograph of a longitudinal section through a node of yellow-stripe diseased and cankered cane, showing a group of plasma-filled cells at X. (× 50.)

In examining these sections with the microscope it is at once apparent that the granular substance is made up of a mass of small hyaline bodies more or less uniform in size. However, their exact size and form could not be ascertained, due to the fact that the whole mass is in the form of a compact plasma. The hyaline bodies

which are dotted throughout the mass are less than one micron in length in sections from freshly cut cankered cane. They more nearly resemble nuclear granules in a mass of cytoplasm. They are less clearly defined than masses of bacteria.

Early attempts to induce growth development in agar from the above plasma-filled cells have failed. It was thought advisable to observe the condition of cankered cane in more than one stage.

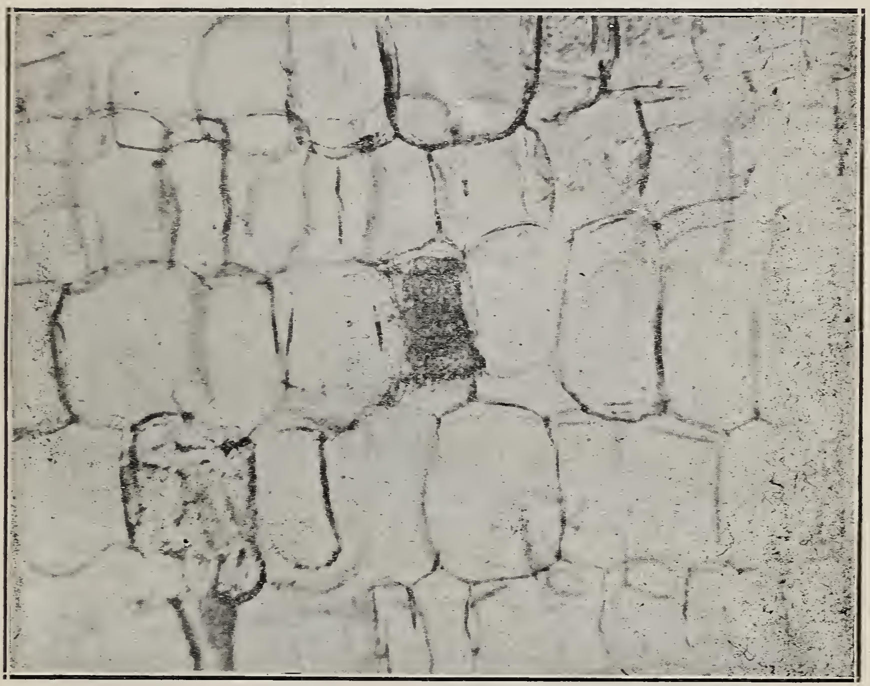


FIG. 8.—Photograph of a section through an interior canker of yellow-stripe diseased cane, showing in the center and near the lower left-hand corner single cells filled with finely granular plasma. (× 250.)

Therefore such cane was collected from three different parts of the Island, south coast, north coast, and northeast section. The local and scattered plasma-filled cells were found in the cane from the three parts mentioned and in the varieties Rayada, Cavengerie or red cane and other kinds. In growing cane the condition of the plasma-filled cells were similar in all canes examined. Some of the cankered cane was kept in a covered chamber for two months, so that the cane

became devitalized and yet not much dried out. Free hand sections of this material showed the granular plasma material in the parenchyma cells in the same proportion as in freshly cut cane, but the

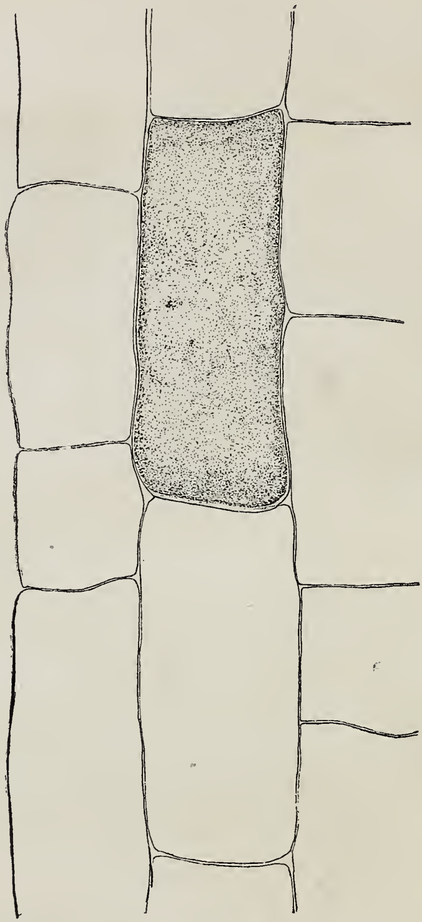


FIG. 9.—Camera lucida drawing of a plasma-filled cell in an internally discolored area in yellow-stripe diseased cane stalk. (× 333.)

granules in the former were more distinct, irregular in form, elongated and somewhat larger. In addition rotary movement of the individual minute bodies within the host cells was distinctly notice-

able. It appeared that growth or a separation into more distinct individuals took place. It was very clear from the material at hand that the compact plasma in the cells of freshly cut cankered cane were in every way similar in appearance and distribution to the plasma in the cells which were seen in the more devitalized cane, only that in the latter more distinctness was observable. However, it was felt that sugar-cane treated in this manner is bound to become overrun with microorganisms and so more cankered cane was obtained, sterilized in bichloride of mercury and kept in the moist chamber for daily observation. It was found that in the course of two days some

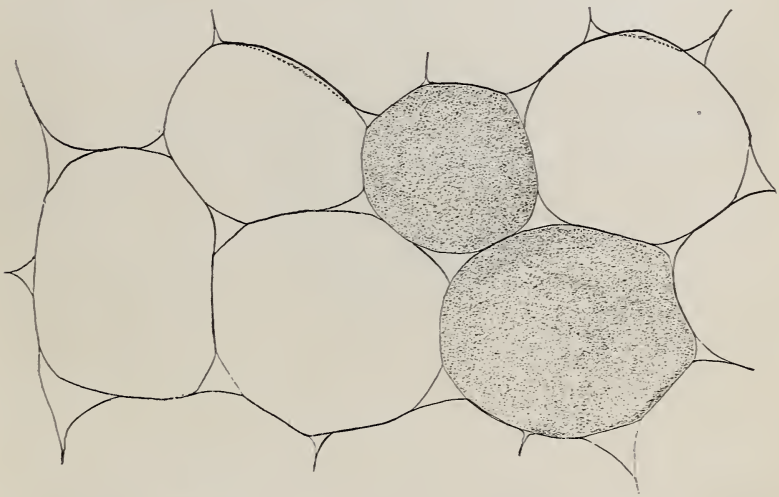


FIG. 10.—Same as in Fig. 9, in cross section. (× 333.)

cankered cane showed a greater distinctness in the granulation of the characteristic plasma-filled cells, and that after eight days motility was observed in the plasma mass. As to the exact nature of this organism in the cankered cane cells nothing more definite can be said until more data is obtained in the process of investigation.

In cane otherwise diseased or injured by borers or fungi a reddish discoloration usually is found, but it is more or less continuous and is confined more to the vascular bundles. Such bundles often contain a homogeneous gummy substance which is not at all like the substance in cankered cane parenchyma cells. Discoloration of

parenchyma cells in non-yellow striped cane may also occur but the discoloration is not of the same character as in yellow-stripe disease tissue. In cane diseased because of an invasion of fungi or other destructive agents the discoloration is more confined to the phloem and vessels and to the cell walls of parenchyma. A red phloem and gummed vessels are signs of wilt and decay due to fungi, bacteria, insects or mechanical injury. A continuous cavity in the pith or center of the stalk is a common effect of fungus invasion.

Further work is being done and planned with the view to clear up some of the phases of the problem of yellow-stripe disease.

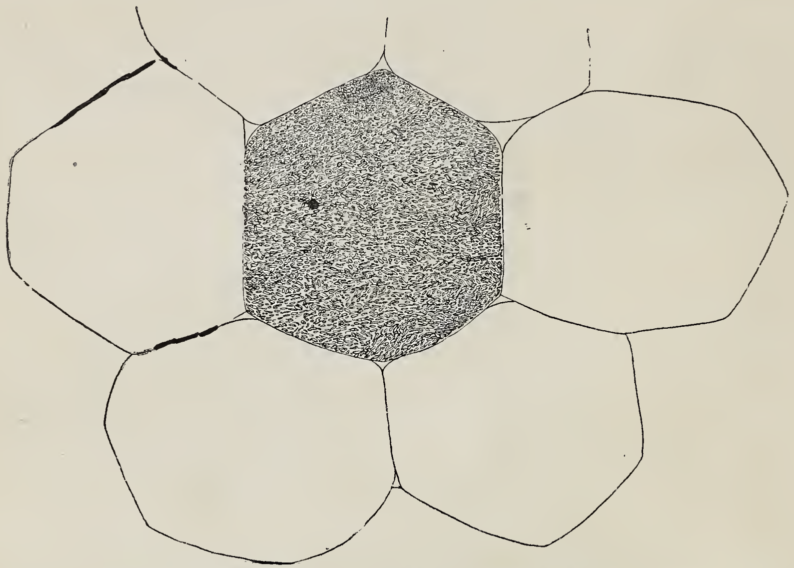


Fig. 11.—Drawing of a section of yellow-stripe diseased cane tissue two months after the cane was cut. (× 400.)

From a study of the internal structure of cankered cane it is clear that actual deterioration and breaking down of cells in the interior of cane in an advanced stage of the yellow-stripe disease takes place. This effect is due to no other cause than to the destructive action of the infective substance of yellow-stripe disease, as there is apparently no connection between these interior sick cells and other outside mechanical or organized agencies. Furthermore, this substance, resembling a *Plasmodium,* in some of the interior cells was found to be constantly associated with yellow-striped cane in an advanced stage of disease.

INSECTS AND MOTTLING DISEASE.

By E. Graywood Smyth, Chief, Division of Entomology.

The fact has been brought out by Professor Earle, in a preceding page, that most previous investigators of the sugar-cane mottling (or "yellow stripe") disease, notably in Java and Hawaii, have dealt with it as an inheritable bud variation and have failed to recognize its infectious nature, or at least to consider it as an important factor from an economic standpoint. Even in Porto Rico the infectious character of the disease was not recognized until the latter part of 1917. It is not surprising, therefore, that few attempts have been made, previous to the present work, to demonstrate a possible connection between insect attack and secondary infection with mottling disease.

The laboratory experiments detailed in this report were started in the spring of 1918, but had been preceded by a considerable amount of field work, made in the districts where the injury from mottling disease was most acute, in attempt to ascertain what insects might be concerned in the spread of the epidemic. In the experiments, four successful inoculations by insects have resulted, to date, while no control plants have become diseased, which would seem to fasten the responsibility, in these cases at least, upon the insects as carriers of the virus. It is felt, however, desirable to obtain duplications of the few positive results before conclusion may be safely drawn that insects are a principle means of communicating the disease.[1]

The idea that insects might carry the disease in Porto Rico found its origin in the knowledge of a number of unique, well-established facts:

1. Mottling disease is spread not alone by planting infected "seed," but may easily communicate itself to plants germinated from healthy cuttings. Experimental evidence tends to show that this spread of infection takes place neither through the soil nor by physical contact.

2. Such natural agencies of spread of disease as wind and surface water cannot account for the equal and general spread of mottling disease in all directions from infected to healthy plants.

[1] Since the above was written, two additional plants have become mottled (diseased) as result of the attack of virus-bearing *Stenocranus saccharivorus*, and three others have shown positive secondary infection (inoculation) in cages containing both cane-fly and yellow aphis. No control plants have yet become diseased.

3. Secondary infection is by no means confined to the plants immediately adjacent to diseased plants, but may occur on isolated plants at considerable distance from the seat of infection.

4. The rate of spread varies greatly with the season, not apparently in conformity with any seasonal abundance of wind or rainfall, nor with the amount of irrigation or cultivation, but in possible (if not probable) conformity with the seasonal abundance of certain insect pests.

5. Some very similar diseases of other cultivated plants, notably those known as virus diseases (such as mosaic diseases, spinach blight and sugar-beet curly-leaf) have been proven to be carried by insects; and in the case of some of them there has been found no other means of communicating the disease than by insects.

6. The two classes of insects proven to act most commonly as vectors of virus diseases—the leafhoppers and the plant-lice—are well represented among sugar-cane pests, and are often abundant in cane fields of the Island.

The accompanying tables (Tables I and II) give the names and hosts of a number of plant diseases occurring in the States that have proved to be transmitted, at least in part, by insects. An attempt has been made to show in these tables what characteristics the cane mottling disease has in common with other insect-borne diseases, and in what important details it differs from one or another of them.

Field Evidence in Support of Insect Transmission.

From such data as has been accumulated from field trips over the Island, it appears that there is no single species of cane-infesting insect or mite sufficiently common and prevalent in all districts, and at all seasons, where the disease is present and spreading, to account for the very general "run" of epidemic that has occurred.

If it shall later develope that several insects are concerned in the spread of the disease—and the results of our experiments to date lead to that belief—then we may possibly attribute the spread of the epidemic to one or another prevalent pest in each district where spread has been in progress. For instance, during periods of most rapid spread in the Guánica and Ponce districts, the yellow thrips has been the prevailing cane pest, and in fact the only one present in large numbers on both young and mature cane, and therefore the only one which might account for wholesale secondary infection in both young and mature cane. Rapid spread of mottling disease observed on numerous occasions in the Arecibo section might have been

blamed upon the green leafhopper, which occurred in all fields, particularly of young cane. On some occasions, local rapid spread of the disease has been observed to occur simultaneously with abundance of the yellow cane aphis, and this has seemed at the time significant. The spread of mottling disease in fields of the experiment station at Río Piedras has occurred usually at times when there was considerable cane-fly present in the fields, but no other cane pest that seemed to be able to account for the spread.

In the following paragraphs will be discussed briefly the cane insects which may be suspected of having possible connection with spread of the mottling disease, from a judgment based purely upon field observations.

Cane Insects as Possible Carriers of Mottling Disease.

THE YELLOW CANE THRIPS (*Frankliniella* sp.).

This small thrips has been observed for the past two years to be very abundant on young to half-grown sugar cane in fields on the south coast, in the Guánica and Ponce districts. It is most prevalent in the winter season, which is the time during which spread of the disease is most rapid. It is the only cane pest of those districts that has been found universally present, in large numbers, in both young and mature cane, being considerably more abundant, however, in the young cane. The ratio of its numbers in young and mature cane bears, in fact, a striking similarity to the proportion of secondary infection in young and mature cane. These thrips lay their eggs in the cane leaves, and breed in large numbers between the terminal, young, unfurled leaves, where their attack scarifies the leaf surface along the midrib, near the base of leaf, causing white scars that later turn brown. Young plants two to three feet in height often bear dozens of the thrips among their terminal leaves, which are not very visible except by tearing open the terminal bud; and it has been noted that the first evidence of mottling on a young plant usually occurs near bases of the terminal leaves in the region showing attack by this thrips.

This insect has not been noticed in abundance in other parts of the Island, though on one occasion it was found in young canes in a field at Río Piedras, during a dry spell, which indicates that it may also occur at other points along the north coast at some seasons. The adults are strong fliers, and could spread rapidly to other parts of a field from a few infected canes. Such search as has been made

TABLE

A SUMMARY OF OUR KNOWLEDGE OF INSECT-BORNE

Name of Disease	Principal Economic Hosts	Other or Wild Host Plants	Nature of Disease
1. Hawaiian Cane "Root Disease" (*Ithyphallus coralloides*).	Sugar cane...........	Lantana and other roots.	Fungus.....
2. White Pine Blister Rust (*Cronartium ribicola*)	5-leaved pines (18 spicies).	*Ribes* spp............	Fungus.....
3. Chestnut Blight (*Endothia parasitica*).	Chestnuts and chinquepin.	....	Fungus.....
4. Currant Stem Blight (*Botryosphaeria ribis*).	Currant and gooseberry.	Wild spicies of Ribes	Fungus.....
5. Tree-cricket Canker (*Leptosphaeria coniotherium*).	Raspberry ("Cane blight").	Apple, rose and elm.	Fungus.....
6. Apple Bitter-rot (*Glomerella cingulata*).	Apple, pear, peach, grape, quince.	Citrus, cocoa, coffee, mango, etc.	Fungus.....
7. Tomato Leaf-spot (*Septoria lycopersici*). (2)	Tomato..............	....	Fungus.....
8. Carnation Bud-rot (*Sporotrichum poae*).	Carnation............	June grass (*Poa pratensis*).	Fungus.....
9. Internal Disease of Cotton Bolls (4 undetermined fungi).	Cotton................	Over 15 plants in 7 families.	Fungus.....
10. Fire Blight (*Bacillus amylovorus*).	Pear, quince, apple, apricot.	....	Bacterial...
11. Bacterial Wilt of Cucurbits (*Bacillus tracheiphilus*).	Cucumber, squash, melon, gourd.	Wild cucurbits.......	Bacterial...
12. Sugar Beet Curly-top.....................	Sugar beet...........	14 known plants in 8 families.	Virus.......
13. Spinach Blight...........................	Spinach.............	Not yet determined..	Virus.......
14. Tobacco Mosaic Disease.....	Tobacco, tomato, pepper, petunia.	*N. rustica*, Jimson weed, and *Hyoscyamus niger*.	Virus.......
15. Potato Mosaic Disease....................	Irish potato.........	....	Virus.......
16. Cucumber Mosaic Disease................	Cucumber, pumpkin, squash cantaloupe	Gourd................	Virus.......
17. Potato Hopperburn (4).....................	Irish potato, apple, raspberry.	Dahlia and box-elder	(?)..........
18. Sugar Cane Mottling Disease.............	Sugar cane, corn?, rice?, millet?	Sorghum, foxtail, crabgrass and Panicum. (5)	Virus (?)...

(*) A continuation will be found in Table II, following. These data have been taken from such sources as were available to the writer, and an attempt was made to make them as complete as possible, for purposes of comparison. The arrangement of the diseases is one of convenience only. A bibliography of the more important writings on insect transmission of plant diseases will be found at the end of this article, on page 112. The vacant spaces and question marks, in this table, serve to show how imperfect is our knowledge of the entire subject of insect transmission of plant diseases, and how great the need of research work along this line to aid in solving important problems of disease control. The deficiency of results from past endeavors to demonstrate insect transmission of disease shows, furthermore, how faulty is our system of technical training as regards a proper appreciation of the close co-ordination of pathology and entomology.

(1) Manner of transmission of the spores or virus by insects concerned. By the term cyclical is meant, substantial proof that the inoculum of disease, taken internally, must un-

I. (*)

DISEASES OF PLANTS OCCURRING IN AMERICA.

Proven Insect Transmitters	Insect Carriers of Viable Spores	Probable or Suspected Insect Carriers	Mechanical or Cyclical (1)	Externally or by Ingestion (1)	Disease
....	Sarcophagid and Muscid flies.	Ants; a beetle; sow-bugs; earwigs.	Mechanical	Both....	1
(Urediniospores) Lepidop. larvae; rose beetle; ants; stink-bugs; a weevil.	Any insect coming in contact with spores.	(Aeciospores) *Porthetria dispar* and *Pissodes.*	Mechanical	Probably both	2
....	Any insect coming in contact with spores.	*Leptostylus maculata*, a beetle.	Mechanical	Both....	3
....	....	*Psenocerus supernotatus*, a beetle.	Mechanical	(?)......	4
Œcanthus niveus; Œ. angustipennis.	Same	*Œ nigricornis: Œ. exclamationis;* bees to the fruit.	Mechanical	Both....	5
Pomace flies (*Drosophilidae*).	Same	Tree-crickets; fruit frequenting insects.	Mechanical	Both....	6
....	Potato beetle; tomato horn-worm; a lady-beetle. (2)	Flea-beetles and leaf frequenting insects.	Mechanical	Both....	7
....	....	A Tarsonemid mite. *Pediculopsis graminum.*	(?)	(?)......	8
Dysdercus spp., *Nezara, Loptoglossus. Phthia.*	Same	....	Mechanical (?)	(?)......	9
Scolytus rugulosus; bees; aphids; *Lygus pratensis; Empoasco mali.*	Same	*Ceresa bubalis;* wasps, flies, ants, thrips, borers, tree-crickets, Elateridae	Probably mechanical	Both....	10
Diabrotica vittata and *D. duodecimo punctata.*	Same	....	Mechanical; doubtfully cyclical	Both....	11
Eutettix tenella............	....	No other	Apparently cyclical	Ingestion	12
Macrosiphum solanifoliae; Rhopalosiphum persicae; Aphis rumicis; Lygus pratensis.	....	....	Possibly both (3)	Apparently both	13
Rhopalosiphum persicae; Macrosiphum tabaci.	....	Flea-beetles; some sucking insects.	(?)	(?)......	14
Rhopalosiphum persicae and another aphid.	....	....	(?)	(?)......	15
Aphis gossypii............	....	....	(?)	(?)......	16
Empoasco mali............	....	No other.......	(?)	(?)......	17
W. I. cane-fly; leaf scale: yellow aphis; mealybug. (6).	....	Yellow cane thrips; shot-hole borer.	(?)	(?)......	18

dergo a period of incubation before it becomes infectious to a healthy plant, which is taken as evidence that it undergoes some change, perhaps cyclical, within the body of insect.

(2) The same insects are reported also as carrying the spores of early blight, *Alternaria solani*, that attacks also potato.

(3) The fact that the virus of this disease may be inherited through several generations of the aphid gives grounds for belief that the transmission is of a cyclical nature.

(4) It has not yet been determined, according to the author of the investigations, whether this malady is a specific disease, though it gives evidence of being one.

(5) The list of host plants of the cane mottling disease is taken from the bulletin by E. W. Brandes, not from the present publication.

(6) As noted in the text, the apparent transmissions resulting from attack of the four insects here listed are considered to require to be experimentally repeated before the evidence against these insects is conclusive.

TABLE

A SUMMARY OF OUR KNOWLEDGE OF

(Continuation

Disease	Length of time insect can carry inoculum	Infectivity inheritable in insect	Other means of natural dissemination
1 Hawaiian Cane "Root Disease"...	6 to 18 hours internally.	No....	Mechanical spread of mycelium.
2 White Pine Blister Rust...........	(?)......................	No....	Wind; rain; animals; birds; nursery stock.
3 Chestnut Blight....................	(?)......................	No....	Wind; rain; animals; birds; nursery stock.
4 Currant Stem Blight..............	(?)......................	No....	Wind....................
5 Tree-cricket Canker..............	Over 20 days externally; 6½ hours to 5 days internally.	No....	(?)........................
6 Apple Bitter-rot....................	(?)......................	No....	Wind and rain from cankers and mummies.
7 Tomato Leaf-spot..................	(?)......................	No....	Hands of pickers; wind and rain.
8 Carnation Bud-rot................	(?)......................	(?)....	(?)........................
9 Internal Disease of Cotton Bolls..	(?)......................	(?)....	None known.......... ..
10 Fire Blight.........................	(?)......................	(?)....	Rain; unsterilized tools; nursery stock; infected prunings.
11 Bacterial wilt of Cucurbits........	Over winter............	No....	Rarely by root contact..
12 Sugar Beet Curly-top..............	Over 111 days..........	No....	None.....................
13 Spinach Blight......................	For 4 successive generations.	Yes...	None known.............
14 Tobacco Mosaic Disease...........	(?)......................	(?)....	Hands of pickers; contact of leaves.
15 Potato Mosaic Disease.............	(?)......................	(?)....	Mosaic tubers; through the soil.
16 Cucumber Mosaic Disease.........	(?)......................	(?)....	None known.............
17 Potato Hopperburn..................	(?)......................	(?)....	Apparently none........
18 Sugar-cane Mottling Disease......	(?)......................	(?)....	Cuttings..................

II.

INSECT-BORNE DISEASES OF PLANTS.

from Table I.)

Successful methods of artificial inoculation	Disease transmitted through soil	Carried through the seed	Transmitted by vegetative reproduction	Infectious by contact or handling	Disease
By mycelium only	Yes	No	Principally	No	1
By spore germination	No	No	No	Urediniospores on currant.	2
By spore germination	No	No	No	No	3
By spore germination	No	No	By cuttings		4
With the excrement of tree-crickets.	No	No	No	No	5
By spore germination	No	No	No	By spore contamination.	6
By spore germination	No	No	No	Very	7
None performed	No	(?)	(?)	(?)	8
None	No	No	No	No	9
Spraying or rubbing with spore-laden material.	No	No	No	Rarely	10
Needle pricks; water suspension of spores poured over soil.	Rarely, when roots are injured.	No	No	No	11
By grafting; no other	No	No	Yes	No	12
Needle pricks; juice of crushed virus-bearing aphids.	No	No	Would be	Yes, if tissue is crushed.	13
Needle pricks; rubbing or spraying with virus.	Rarely, when roots are injured.	No	Would be	Very	14
Injection of or rubbing with virus.	Yes	(?)	Principally	Yes, if tissue is crushed.	15
Needle injections; contact of virus with wounds.	No	(?)	Would be	Yes, if tissue is crushed.	16
None	No	No	No	No	17
(See preceding articles by the pathologists).	No	(?)	Principally	No	18

has failed to reveal the presence of this species on ''malojillo'' (*Eriochloa subglabra*), the common grass of the cane fields, but it is altogether probable that the species may breed in some wild grasses as well as in cane, and this fact will be determined.

THE WEST INDIAN CANE-FLY (*Stenocranus saccharivorus* Westw.).

This green plant-hopper is very generally distributed over the Island in the cane fields, but seems never to become abundant, due, it is believed, to the activity of its natural enemies. These consist principally of three parasites (a Stylopid, a Mymarid and a Dryinid) and a common grass lizard (*Anolis pulchellus*). Because of the close relationship of this insect to the sugar-cane leafhopper of Hawaii (*Perkinsiella saccharicida* Kirk.), which has been accused of causing the destructive rind disease to a great extent in those islands, it is plausible to believe that it might become a factor in the distribution of cane mottling disease in fields where it becomes fairly prevalent. That the cane-fly is capable of very great increase in numbers, and of correspondingly serious damage to cane, in situations where it is not kept in check by rain, high wind, and other natural elements of the weather in addition to its natural enemies, has been shown by its phenomenal increase in the experimental greenhouse of the experiment station, and in certain screen-covered breeding cages, where it has often literally covered the undersides of cane leaves, and caused by its copious secretion of honey-dew a growth of black mold that smothered the lower leaves of the plants. As a cane pest, it must be considered an element of great potential danger in connection with possible spread of mottling disease, if not from its own injuries to cane.

THE YELLOW SUGAR-CANE APHIS (*Sipha flava* Forbes).

This small insect is a source of danger, in connection with the spread of disease, not alone from the fact that it is quite prevalent and generally distributed in cane fields, and often becomes so abundant as to assume the proportions of an epidemic, but also from the fact that it is closely related to certain insects (also aphides) that are known to carry virus diseases in other plants. Such diseases, transmitted by aphides, are the tobacco mosaic, the spinach blight, and the potato mosaic. The yellow aphis has been found prevalent in a number of fields where mottling disease was present and spreading; but there have, at the same time, been fields subject to spread of the epidemic where the yellow aphis was not found; so

that indictment of this insect from field observations alone is not permissible.

THE GREEN SUGAR-CANE LEAFHOPPER (*Kolla similis* Walk.).

This bright green leafhopper, because of its prevalence in fields of young cane in nearly all parts of the Island, was one of the first to fall under suspicion. Its close relationship to the leafhoppers that transmit curly-leaf of sugar beets, and hopper-burn of potato, in the United States is added reason for placing it among the species worthy of investigation. In the laboratory this insect has been reared from egg to adult, generation after generation, on sugar cane, and the frequent finding of nymphs on sugar cane in the fields adds to the belief that it breeds on cane commonly, though perhaps to a greater extent on Para grass (*Panicum bardinode*) and "malojillo" (*Eriochloa subglabra*), its wild food plants.

The two facts which throw question on the possibility of this insect carrying the disease are: first, the fact that it occurs commonly only on cane under three feet high, and rarely on half-grown cane, but almost never on mature cane, whereas secondary infection may take place in cane of any age; and second, the fact that all experimental tests (and there have been more with this than with any other species) have failed to demonstrate its ability to carry the disease.

THE SUGAR-CANE SHOT-HOLE BORER (*Xyleborus* sp.).

This very small boring beetle was observed by the writer, two years ago, to be present and infesting the seed sections from which were sprouting some young canes in the Guánica district that were highly infected with mottling disease. It was stated by the field manager that the seed had come from healthy cane; and observation showed that there was no older mottled cane in immediate vicinity, though fields of mature cane at distances of a quarter to half mile from the young cane were considerably infected. As this insect is known to attack and bore into live standing cane, particularly when soured or unhealthy, it seems not improbable that adults migrating from mature mottled canes in cankered condition, and attacking the seed in the ground before or at time of germination, might easily carry the disease with them and transmit it to the sprouting young canes. Experience in other parts of the Island has shown seed-cane sections in sprouting condition to be very often infested with this pest, so the chance of the disease being thus caried may not be re-

mote. Laboratory tests with the insect have not yet been made. A closely related species of *Xyleborus* (*X. perforans* Woll.) has been accused of complicity in the spread of a sugar-cane disease in Trinidad (see Insect Life, Vol. V, page 51).

THE MEALYBUG.

Of this there are two species, *Pseudococcus calceolariae* Mask. and *Ps. sacchari* Ckll., which are almost indistinguishable except under a microscope, and are apparently about equally common. They attack mature cane on the stalk about the node, protected beneath the leaf sheaths, but on young cane are confined largely to the base of plant and the roots. As mature female mealybugs do not fly, and crawl but very little, they are wholly dependent upon foreign agency for their distribution. This takes place largely through the scattering of infested stalks or cane tops during the hauling, or from scattering by hand. Mealybugs may be carried also on floating fragments of infested cane on irrigation water. Birds may carry the young on their feet, but such dispersion is very limited. It is claimed that ants carry live mealybugs from plant to plant, and thus start new colonies, but this contention needs further corroboration. A field may become infested from insects that migrate upward onto young plants from the infested seed pieces, and is still more often infested from the stubble of the previous crop, or from grass or volunteer cane in the field that has harbored thousands of the mealybugs from the preceding crop. By any of the means here mentioned, mealybugs might be able to carry the mottling disease from a previous to a new crop, and even to spread it to some extent, if it may be shown that they are able to transmit the infective principle of this particular disease; but it is quite inconceivable that an insect so utterly dependent upon human agency for its spread, could be responsible for rapid spread of the disease in a field planted entirely to healthy seed, and in which a previous crop had not been seriously infected—conditions very frequently met with in connection with a study of the mottling disease.

THE CANE RUST-MITE (*Tarsonemus spinipes* Hirst).

This very minute white mite attacks principally the stalk and leaf sheaths, where it forms large clusters of very small, flat brown blisters, that give the plant tissue a scabby or scarred appearance. The mite infests new plants by migrating upward from the infested seed pieces. Its bionomics are little known, but it is possible that

the rust-mite may also be spread by attaching itself to winged insects that frequent the cane, which may carry it to new plants. This is a habit shared by many of the mite pests of plants. Altogether, however, what has been said of the mealybugs, in connection with their possible agency in the rapid spread of the mottling disease, may also be said of this pest. Its means of transportation are too limited to give it serious import in this connection.

THE SUGAR-CANE RED-SPIDER (*Oligonychus viridis?*)

This very small acarid pest of cane, while often abundant and doing damage to cane foliage in our greenhouse and in rearing cages, has not been noted as abundant at any point in the field, and is in fact rarely seen. Being a sucking insect, it may be regarded as a possible disease carrier when abundant. As its principal means of distribution are the wind and other insects, to which it attaches, and to some extent mechanical carriage on clothing or animals, there is probably small chance of its taking any part in a general and rapid spread of the disease.

THE CANE ROOT MITE (*Uropodus* sp.).

This pest was first noted in the Arecibo district more than three years ago when making studies of the sugar cane in connection with mottling disease, and has since been found abundantly at Río Piedras and in other districts. Its damage arises from its attack on the roots, which in some cases it tunnels and severs to a coniderable degree. Although diseased plants seem to be most badly attacked by it and the roots showing its injury are in many cases diseased and partly decayed, it has been found attacking also healthy roots, so in some cases is believed to be the primary cause of the root decay. What connection the root decay accompanying attack of this mite may have with the external symptoms which we know as mottling disease has not been fully worked out, but is the subject of investigation. This animal belongs to a group of mites which possess the habit of attaching themselves to beetles as a means of transportation and distribution.

THE FIRE-ANT (*Solenopsis geminata* Fabr.).

This is the commonest species of ant in the cane fields of Porto Rico, and attends all species of aphis, scale and mealybug. Some of these insects it even protects by building earthen shelters over the

colonies, when these latter occur on the stalk near the ground, and it will attack vigorously any intruder on the insect colonies. The possibility of this ant carrying a disease mechanically on its feet or body, as the gypsy moth larva carries the white pine blister rust or the Colorado potato beetle carries the early blight, is not to be ignored; yet until the mottling disease of sugar cane is proven to be caused by a definite spore-bearing organism capable of isolation and of causing reinfection of the disease in a healthy cane plant, the idea of ants carrying this particular disease need not be looked upon seriously.

CHEWING INSECTS.

What has just been said of the fire-ant, and of its possible ability to transmit the cane mottling disease, may as well be said of the majority of the so-called chewing insects, excepting only those which by habit may bodily leave the tissue of one plant and enter that of another, as does the shot-hole borer or the root mite. Of cane pests like the Lepidoptera that attack the plant only in the larval stage there seems, for the present at least, very remote possibility of the infective principle being transmitted from larva to adult and in turn to the egg and next generation larva, and by that means reaching healthy plants from diseased ones. The idea of Lepidoptera carrying a virus disease by any other means seems still more remote, as larvae seldom feed upon more than one plant, or migrate from plant to plant, between hatching and maturity.

Among leaf-feeders like the Orthoptera (grasshoppers and crickets) and certain Coleoptera (beetles), we have to consider not only the possible transfer of the virus, or inoculum, on the mouth parts, by which means it might be carried from plant to plant, but also the possibility of the ingestion of the infective principle and its later transfer to healthy plants with the excrement of the insect. There are plentiful records of the transfer by this means of spore-bearing diseases, but none to our knowledge of such diseases as do not bear definite sporing bodies.

One other element should be considered, namely, the fact that the chewing insects, though they include over fifty per cent of the cane pests, are very much fewer in numbers in cane fields than the smaller, sucking insects; and during the winter season one may often examine hundreds of cane plants, even in fields where mottling disease is present and spreading, without noting any evidence of the attack of leaf-chewers or stalk-borers. Thus it would seem

difficult to attribute a spread of disease, taking place in all parts of a field, to insects that are nowhere in evidence.

While such a generally prevalent pest of sugar cane as the *changa* (*Scapteriscus vicinus* Scud.) may easily fall under suspicion as a carrier of mottling disease, we cannot ignore the fact that the rapid spread of the disease has in no instance been found to coincide with the areas most heavily infested with *changa*, and in many fields of heavy soil where no *changa* was present the disease has spread alarmingly.

Experimental Methods Employed.

Some difficulties have been experienced in developing methods for confining insects upon living cane plants—upon large numbers of plants—in such manner as not to interfere with the natural growth of the plants nor to disturb their root systems. Our first experiments having demonstrated that the transference of the disease through insect attack takes place rarely, and only under very favorable conditions, it became plain that we must subject large numbers of plants to insect attack in order to entertain any hope of obtaining results. This rendered it impossible to use the sort of cloth-covered cages, placed over field-grown plants, that are usually employed in plant-disease transmission experiments. Other methods were therefore devised. The following four methods have proven satisfactory, for experiments with different kinds of insects or different ages of cane plants.

(*A*) Screen-covered cages 3 feet square and 6 feet high, placed over field-grown cane, one containing mottled plants and the others healthy cane. These are adaptable for the larger insects. A number of insects are introduced into a cage with mottled cane. At end of a determined period, which may vary from a few hours to a number of days, as many as possible of the insects are recaptured in the cage containing diseased cane, and transferred to one containing healthy cane, where they remain for another determined period of time. They are then removed from cage and the cane is watched, week after week, for appearance of mottling.

(*B*) Cages of same size as preceding, either screen or cloth covered, but containing both healthy and diseased cane, planted simultaneously. When cane has reached a desired height, insects of a given species are introduced, and the healthy cane is watched thereafter for appearance of disease.

(*C*) Insects collected on mottled cane in the field are transferred,

either individually or in numbers, onto single potted young cane plants, germinated under cover, in confinnement of glass lamp-chimneys or cylinders of fine wire screening, as the size of the insect may require. The healthy cane is subjected to attack for a determined interval of time, when the insects are removed and the cane transferred to the open field.

(*D*) Insects reared in confinement on mottled cane plants, or confined on mottled plants for a known length of time, are transferred to healthy young plants in confinement, as in preceding method.

Checks and Controls.

Throughout the course of the experiments there has been an effort to keep growing, side by side with test plants and under exactly similar conditions of growth, cane plants of the same age which were not subjected to attack of insects previously fed on mottled cane. These were the check plants, or controls, and were of three classes:

(*a*) Simple checks. Plants identical with test plants, but subjected to no artificial treatment whatever.

(*b*) Control plants which had introduced into cages with them, at same time that insects were introduced with test plants, portions of leaves of mottled cane bearing no insects. These were used usually as check on test plants with which it was necessary, or convenient, to introduce portions of the plant bearing the insects from mottled cane, and such controls were designed to show that infection had not resulted from the portions of mottled plant, but from the insects.

(*c*) Control plants having introduced into cages with them a number of insects equal to that introduced with the test plant and of same species of insect, but the insects collected from healthy and not from diseased cane.

In the earlier experiments, it was customary to grow only one or two checks, or controls, with each series of test plants; and a few series of test plants were, principally through oversight, unaccompanied by checks or controls. In the later experiments, however, greater accuracy was maintained in this regard, and a check plant, or control, was grown side by side with every test plant.

It is noteworthy that, while four distinct cane plants became infected with mottling disease in our experiments, apparently as result of insect transmission, no checks or controls became similarly infected. (See foot note on page 83.)

Two control plants did contract the disease, but only by secondary infection, after they had grown beside mottled plants in the field for periods of 3 and 3½ months.

Secondary Infection Among Experimental Plants.

As has been mentioned in preceding discussion, the mistifying feature connected with secondary infection is that it is not confined to the plants growing immediately adjacent to diseased plants, but may occur on isolated plants at some distance from the seat of infection. That the adjacent plants are, however, most apt to contract disease, or at least, to contract it first, seems fairly well established. In proof of this statement may be given our experience in the plots of experimental cane plants on the grounds of the experiment station.

As it has been our desire to prevent the disease from gaining a foothold in station fields, efforts have been made to avoid growing mottled canes outdoors, in exposed situations, for any length of time, where they might become a source of secondary infection. The first two canes that became infected with mottling in our insect transmission experiments were never transplanted to the field, as they gave evidence of infection prior to date of transplanting. The last two, however, were transplanted to field before attack of the disease became evident: and so it happened that they were allowed to remain, in diseased condition, among healthy plants for a period of three to four months. They were intentionally left, as it had seemed that secondary infection had ceased to occur at Río Piedras. As result of these two plants (Nos. 531 and 577), however, secondary infection did occur, the disease showing up simultaneously in two control plants (Nos. 531 *a* and 577 *a*) that were planted immediately adjacent to the test plants. The length of time required for secondary infection to become evident, after the date on which infection had appeared in the test plants, was three months in the one case and three and a half months in the other.

It may be remarked here that, five days after the secondary infection had appeared in these two check plants (on January 31st), both they and the two mottled test plants were transplanted to large cans in the green house, and 16 days later (on February 16th) the symptoms of disease appeared in another plant in the field, as result of secondary infection. This time it was a test plant that became mottled (No. 530), which had stood next to the mottled plant 531, but on opposite side of it, in the row, from the check plant (No. 531 *a*).

As for the insects present in the experimental plat that might have been responsible for the secondary infection, there have been rather few species, and none of them abundant. Some yellow aphis has been present and some cane-fly, and while the plants were still small the green leafhopper was very common. Presence of ants (*Solenopsis geminata*) and their earthen shelters about the roots also indicated that some mealybug was present. No other cane-feeding insect than these was seen on the plants. Of course, the mealybugs and yellow aphis originally infesting the plants had been transferred along with them to the field; but of these two, the yellow aphis had not multiplied on them, but had gradually disappeared.

Another matter worthy of note, in connection with a discussion of secondary infection, is the fact that no transmission of the disease to canes in the experimental plat has taken place in over a year, other than the three plants mentioned above, in spite of the fact that not ten paces from the plat is the greenhouse in which dozens of exposed mottled canes have been constantly growing. Both doors of greenhouse have been wide open on many occasions, a ventilator in the roof has been open nearly a foot, quite continuously, and the two ends of building are covered only with a screening of wide mesh (seven strands to the inch), leaving apertures large enough for the cane-fly, yellow aphis and red-spider, the three worst pests in the greenhouse, to pass with ease. It is difficult to see why these three pests, if capable of carrying the disease, should not have carried it from the greenhouse to the outdoor plat in a year's time.

The idea that ants may carry the mottling disease seems also to find poor substantiation from the fact that screened cages containing mottled canes have stood immediately adjacent to the experimental plat for more than a year and the ants have moved rather freely through the meshes of the screening; yet no secondary infection has taken place from this source. Within the greenhouse, mottled and healthy plants have on some occasions grown side by side in a pot or can for months, both infested with mealybug and equally attended by the ants, without any transference of the disease.

As has been stated by the pathologists, some secondary infection has taken place in the greenhouse, where over a hundred cane plants, mottled and healthy mixed, have been growing constantly; but this infection has seemed small, quite out of proportion with the great abundance of insects in the greenhouse, particularly of the three pests mentioned in a previous paragraph (the cane-fly, yellow aphis and red-spider).

Results of the Transmission Experiments.[1]

THE GREEN SUGAR-CANE LEAFHOPPER (*Kolla similis* Walk.).

The first experimental tests made with this leafhopper were by method A. the length of time during which the leafhoppers were confined on the mottled cane varying from a few hours to a week. and the number of individual hoppers employed varying from 4 to 39 (see Table III).

Two tests were made by method B, 48 adults being used in each instance (see Exps. 283 and 284 in Table IV).

By methods C and D, 91 plants were tested with this insect. using both nymphs and adults, the number of individuals employed per plant varying from 1 to 7. In some cases individuals confined on healthy plants were of the third and fourth generation that had fed almost continuously upon mottled cane.

The results of all experimental tests made with this leafhopper were negative.

Table III.

FIRST CAGE EXPERIMENTS WITH *KOLA SIMILIS* WALK.[2]

Date	No. of Adults	Period of Previous Feeding on Mottled Cane	Results
July 25	39	7½ hours	Negative.
" 24	14	1 day	"
" 18	21	2 days	"
" 22	4	3 "	"
" 26	10	3 "	"
" 22	9	4 "	"
" 15	8	6-7 "	"
" 16	30	7-8 "	"

Successful inoculations, none.

[1] In each case of infection with the mottling disease as result of attack by insects in confinement, the true presence of the mottling symptoms was verified by at least two other experts of the station staff in addiion to the writer, usually the director and one of the pathologists, Professor Earle or Mr. Matz.

[2] In these transmission experiments method A was used (see page 95,) and the leafhoppers remained on the healthy cane plants until they died or disappeared.

TABLE IV.

EXPERIMENTS WITH *KOLLA SIMILIS* WALK.

Plant numbers	No. of test plants	No. of check plants	Date of confinement	Insects confined per plant	Days insects confined	Cane trans-planted	Plants became diseased	Date disease appeared	Check plants diseased
157 to 161	5	2	January 10	1 Adult	4-10	February 3	None	....	None
176 & 177	2	1	" 10	1 "	17-31	" 15	"	....	"
216	1	1	" 20	1 "	12	" 17	"	....	"
217	1	0	" 31	1 Nymph	7	" 17	"	....	....
218 to 222	5	2	" 31	1 Adult	7	" 20	"	....	None
224	1	0	February 1	1 "	6	" 24	"	....	"
226	1	1	" 7	1 Nymph	17	" 24	"	....	....
227 to 230	4	2	" 7	1 Adult	17	" 24	"	....	None
239	1	0	" 7	1 Nymph	12	" 19	"	....	"
240 to 214	5	2	" 7	1 Adult	12-14	" 19 to March 14	"	....	....
255 to 258	4	0	" 19	1 Adult	21-22	March 14	None	....	None
259	1	0	" 20	2 Nymphs	21	" 14	"	....	....
267	1	0	" 22	5 "	20	" 14	"	....	....
268	1	0	" 23	1 Adult	19	" 15	"	....	....
269	1	0	" 23	7 Nymphs	19	" 15	"	....	....
270 & 271	2	1	" 24	1 Adult	19	(Both died)	....	....	....
272	1	1	" 24	3 Nymphs	19	March 15	None	....	None
274	1	0	" 24	5 "	19	(Died)	....	......	"
283 & 284	2	1	" 25	48 Adults	1 month	***	None	....	None
287 to 290	4	2	" 26	1 Adult	17	March 15	"	....	"
294	1	0	March 10	4 Adults	3	" 14	"	....	"
302 & 303	2	0	" ?	3 Nymphs	?	" 17	"	....	....
304	1	0	" ?	1 Nymph	?	" 17	"	....	....
312	1	1	" 14	4 Adults	16	June 2	"	....	....
315	1	1	" 14	2 "	43	April 29	"	....	None
338 to 343	6	0	" 17	1 Adult	43	" 29	"	....	"
344	1	0	" 14	2 Nymphs	43	" 29	"	....	....
361	1	0	" 31	2 Adults	24	" 29	"	....	....
362 to 369	8	0	" 31	1 Adult	24	" 29	"	....	....
370 to 373	4	0	" 31	1 Nymph	26	" 29	"	....	....
422	1	0	April 28	2 Nymphs	**	....	"	....	....
435 to 442	8	0	" 30	2 "	**	August 4	"	....	....
443	1	1	" 30	3 "	**	" 4	"	....	None
454 to 461	8	2	" 30	1 Adult	**	" 5	"	....	"
463	1	0	May 27	2 Nymphs	**	" 6	"	....	....
478	1	0	" 31	2 Adults	**	" ?	"	....	....
489 & 490	2	0	June 2	2 "	**	" 13	"	....	....
491	1	1	" 2	3 Nymphs	**	" 13	"	....	....
Total	93	22	....	....	....	....	None	....	None

* Plant died.

** The insects were not removed from these plants up to the time the latter were transplanted to field.

*** Tests made by method B.

THE WEST INDIAN CANE-FLY (*Stenocranus saccharivorus* Westw.).

Trials with this insect were made mostly by the last two methods, C and D, though two tests were made by using method A (Exp. Nos. 316 and 325) and four by method B (Exp. Nos. 506, 508, 510 and 512). A total of 87 tests was made, of which number only one test gave successful transmission. The plant that became infected, No. 377, was one of a series of three plants, each subjected, on March 31st, to attack of two adults taken from leaves of mottled cane in the greenhouse. The plant showed, by April 29, no apparent signs of mottling. On May 27, however, when next examined, it presented a very aggravated case of the disease, which must have become apparent very early in May.

TABLE V.

EXPERIMENTS WITH *STENOCRANUS SACCHARIVORUS* WESTW.

Plant numbers	No. of test plants	No. of controls	Date of Confining Insects	Insects Confined per Plant	Days Insects Confined	Date Plant put into Field	Test Plants Became Mottled	Date Mottling Appeared	Controls Became Mottled	Date Mottling Appeared on Controls
183 - 186..	4	2	1/20	1 adult....................	11±	2/17	None	......	None	......
187 - 188..	2	1	"	2 nymphs.................	28	2/17	"	......	"	......
189 - 190..	2	1	"	6 "	28	2/17	"	......	"	......
246 - 252..	7	2	2/17	1 adult	7	2/25	"	......	"	......
254	1	0	2/19	30– nymphs	(n)	3/14	"	......	....	......
275	1	0	2/8	30± "	25	3/15	"	......	....	......
276 - 279..	4	2	2/24	1 adult....................	19	3/17	"	......	None	......
280	1	1	"	2 adults....	19	3/17	"	......	"	......
316	1	0	3/14	100± nymphs	(n)	***	"	......	....	......
325	1	0	3/17	100– "	(n)	***	"	......	....	......
326 - 329..	3	1**	"	10 nymphs.......	(n)	4/29	"	......	None	......
330	1	0	"	1 adult.............	16	4/10	"	......	....	......
331 - 336..	6	1	"	1 nymph..................	16	4/10	"	......	None	......
376 - 378..	3	0	3/31	2 adults	29	[illegible]2	One	5/27	....	......
383	1	0	4/10	6 nymphs	17	4/29	None	......	....	......
384	1	0	"	6 adults....................	17	4/29	"	......	....	......
385 - 387..	3	0	"	5 "	17	4/29	"	......	....	......
406	1	0	4/25	8 "	.....	(Died)	....	......	....	......
533 - 536..	4	4	9/30	12– nymphs..............	15	10/15	None	......	None	......
554 - 555..	2	2	10/10	24– "	20	10/30	"	......	"	......
556 - 562..	7	7*	10/11	12– "	6±	10/17	"	......	"	......
586 - 591..	6	6**	10/22	40± "	5+	10/27	"	......	"	......
600	1	1**	10/23	Many nymphs and adults	20+	11/12	"	......	"	......
608 - 618..	11	11*	10/30	24+ nymphs...............	13+	11/12	"	......	"	......
625 - 633..	9	9*	11/12	30– "	12+	11/24	"	......	"	......
506 - 508..	....	......	......	....	......	....	....	....	....	......
510 - 512..	4	0	8/12	Many nymphs and adults	(n)	***	None	......	....	......
Total..	87	51	......	....	......	....	One	......	None	......

* Control plants of style *b* used.

** Control plants of style *c* used.

*** These plants were in an outdoor cage.

(n) Insects were not later removed from test plants, so exact length of exposure is not known.

THE MEALYBUGS (*Pseudococcus calceolariae* Mask. and *Ps. sacchari* Ckll.).

Because of the very close relationship and resemblance of these two species—it being impossible to separate them without microscopic examination—and because their habits are so nearly identical, no attempt was made to distinguish or separate them for experimental purposes.

Tests made with mealybugs were all by use of the last two methods, C and D. A total of 40 tests was made, of which number one test plant (No. 577) became infected with mottling disease, apparently as result of transmission by the mealybug.

This was one of a series of seven plants, each subjected, on October 21st, to the attack of 6 adult female mealybugs from mottled cane. For each plant of the series there was grown a control, kept under exactly similar conditions to the test, and having introduced upon it approximately the same number of insects as the test, but insects taken from healthy instead of mottled cane. The plant that became infected first showed indications of disease on November 23rd, a month and two days after introduction of the insects onto plant. The note of this date reads: "Plant shows evidence of mottling near the bases of two uppermost leaves." Note of December 2nd reads: "Plant is becoming quite decidedly mottled, though check plant, No. 577 *a*, shows no sign of disease."

The notes on this plant further show, however, that the check plant also became mottled, the first symptoms becoming manifest on January 26th, over three months after the mealybugs were introduced with plant. There is little doubt that the inoculation of the check plant can be justly considered to have resulted from secondary infection from the test plant, No. 577, in the interim since they were transplanted, side by side and without cover, into field on October 30th.

TABLE VI.

EXPERIMENTS WITH *PSEUDOCOCCUS CALCEOLARIAE* AND *PS. SACCHARI*.[1]

Plant numbers	Number of test plants	Number of controls	Date of confining insects	Insects confined per plant	Days insects confined	Date plant put into field	Test plants became mottled	Date mottling appeared	Controls became mottled	Date mottling appeared on controls
231 to 328..	8	2	2/7	1 Adult......	11—	2/18	None...	......	None...	
321 to 324..	4	2	3/15	1 "	*	4/28	" ...	......	" ...	
473 to 476..	4	1	5/30	15 Adults.....	74—	8/12	" ...	......	" ...	
502.........	1	0	8/5	15 Nymphs...	65—	10/9	" ...	......	....	
516 to 520..	5	1	9/29	10 " ...	18—	10/17	" ...	......	None...	
521 to 522..	2	1	9/29	2 Egg batches........	18+	10/17	None...	......	None...	
573 to 579..	7	7**	10/21	6 Adults.....	94	10/30	One.....	11/23	One.....	1/26***
580 to 585..	6	6**	10/22	24 Adults and Nymphs ...	81	10/30	None...	......	None...	
595.........	1	1	10/23	7 Nymphs...	*	....	" ...	......	" ...	
596 to 597..	2	2	10/23	15+ " ...	*	....	" ...	......	" ...	
Total....	40	23	....	....	......	....	One.	......	One***	

(1) It has been impracticable to attempt separation of these two species.

* Insects were not later removed from plant, so exact length of exposure is not known.

** Control plants of style *c* used.

*** As over three months elapsed from the time that insects from healthy plants were introduced onto this control (No. 577 a) before it showed mottling, and as it was contiguous and within ten inches of test plant No. 577 that became mottled, the control is considered to have become diseased as result of secondary infection.

THE YELLOW SUGAR-CANE APHIS (*Sipha flava* Forbes).

It is a matter of regret that a larger number of tests was not conducted with this species, which shows some promise of being one of the principal vectors of the disease. One reason for this statement is the fact that cane plants that are subjected when quite young to the attack of large numbers of the yellow aphis transferred from mottled cane, very early show a kind of very characteristic, long, yellow striping on the leaves, which does not appear on the check plants. This is not considered to be a direct result of the punctures of the aphis, as that manifests itself in another manner, namely, in a dull scarlet stain appearing first near the tips of leaves, where the aphids are most numerous, and extending gradually toward base of leaf. The yellow striping appears along the full length of leaf, not only on the leaves attacked by aphis but on others as well. Unfortunately, many of the plants which displayed the yellow striping most strongly died when they were transferred to field, appearing as if weakened by the condition. A few others recovered entirely from the striped condition. So there is not yet sufficient proof to establish a definite connection between this yellow striping and the

mottling disease, but it is the intention to make further experiments to ascertain if there be a connection.

Only 21 experimental tests were made with the yellow aphis, all of them being by the last two methods, C and D. Of this number, one plant gave evidence of successful transmission of the disease by means of the insect. This plant (No. 531) was one of a series of twelve plants, all similarly subjected to the attack of yellow aphids from mottled cane on September 29th. The first evidence of infection was on October 9th, the note for which date reads: "This plant shows every evidence of being in the first stages of the mottling disease." A later note, of October 30, reads: "Shows advanced stage of attack by mottling disease so far as foliage striping is concerned."

It will be noted that the incubation period of the disease was in this case very short—only 10 days—where in other cases of experimental inoculation by means of insects it has been usually about one month. No explanation has been found for this difference. (See Table VII, page 108.)

THE SUGAR-CANE LEAF SCALE (*Pulvinaria iceryi* Guer.).

This long, pink and green scale, which infests only the leaves, is a species so rare in the cane fields of the Island that there seems small likelihood of its ever becoming an important agent in the transmission of the cane mottling disease. So far as we know it has been observed and collected only by the writer, who found it first on sugar cane in an outdoor breeding cage at Santa Rita, on the south coast, on October 3, 1914, and again on December 26, 1914, in the same rearing cage, on which occasion it was recorded as highly parisitized by two small wasps, a black one and a still smaller yellow one.

The scale was not again observed until the spring of 1918, when the writer found it heavily infesting a cane plant in the experimental greenhouse of the station at Río Piedras; and on this occasion also it was heavily parasitized by the two species of Chalcidids. These facts would lead to a belief that both the scale and its two parasites are endemic to the Island, though not yet observed in cane fields.

In the late summer of 1918 specimens of this scale were sent at my request by Mr. M. A. Crespo, then assistant entomologist of the station, to Dr. L. O. Howard, entomologist of the U. S. Department of Agriculture, and the species was determined by Mr. H. Morrison, of the federal department, as *Pulvinaria iceryi* (Guer.), a species previously recorded only from Mauritius and Reunión. If it proves

true that this scale is identical with the "poche blanche" of Mauritius, but is indigenous to Porto Rico, it may turn out to have been introduced into Mauritius from this Island, and will constitute a very parallel case to that of the introduction of *Phytalus smithi* Arrow from Barbados into Mauritius—a case in which a species held in natural check in its native environment, greatly multiplies and becomes a serious pest in the new environment, where it is freed from its parasites.

For the past year this scale has been reared generation after generation on cane in confinement, but when infested canes are transplanted to the outdoors the scales soon disappear from the plants.

Only 14 experimental tests were made of the possible transmission of cane mottling disease by this scale, and of this number, one successful inoculation resulted. This plant (No. 426) was one of a series of four test plants, each subjected on April 28th to the attack of from 5 to 10 adult scales transferred from mottled cane. First evidence of the disease appeared on May 31st, on which date the following note was made: "Plant shows none of the mottling due directly to scale attack, as in 423 and 425, but the terminal 2 leaves show strongly a mottling very similar to mosaic disease." A later note, of July 22nd, reads: "Plant is most decidedly mottled now, and quite heavily infested with the scale."

As to the direct injury to young cane plants from attack of the scale, mentioned above, a note concerning another test plant of the same series (No. 423), under date of May 31st, may be quoted: "Some lower leaves show a peculiar yellow mottling, more profuse and quite unlike the mosaic disease (which appears in terminal leaves first). This is especially true of leaves most heavily infested with scale." This mottling effect on the foliage was of a rather different nature than the yellow striping caused on young plants by aphis attack, but like it, seemed to disappear as a plant increased in growth, so its connection with the mottling disease is doubtful. (See Table VII, page 108.)

THE YELLOW SUGAR-CANE THRIPS (*Frankliniella* sp.).

This thrips appears to be an undescribed species of the genus, and will be described by the writer in an early number of this journal. The pest and its damage have been fully discussed in a previous paragraph.

Seventeen test plants were subjected to the attack of this thrips, but no succesful inoculations resulted. This may have been due,

however, to the fact that the living specimens which were introduced into cages with young plants had been brought across the Island from the south coast, and were one to two days on the journey and weakened to a certain extent, many of them having died *en route.* The species has not been found in sufficient numbers on cane at Río Piedras to make experimental tests. It is the intention to make further tests with this insect in the coming year. (See Table VII.)

THE BLACK SUGAR-CANE THRIPS (*Haplothrips tibialis* Hood?).

This insect has been doubtfully refered to the above species of Hood on the strength of that species having been described from a thrips collected on sugar-cane at Río Piedras; but the description is not at present available. In Moulton's key the insect runs to the genus Anaphothrips.

In habits this species differs from the yellow cane thrips in that both nymphs and adults live near the extremeties of the leaves, never at the bases. The species may be found on young cane only, and seldom becomes abundant. Usually only isolated individuals are found. Specimens were first noticed on grass blades on March 13th, both adults and nymphs, but when transferred to a young cane they continued to thrive, and by April 25th had become so numerous on the cane plant as to cause its death. The leaves were entirely speckled with brown from the attack. From April through June succeeding generations were reared on cane. Under outdoor conditions, the insect is probably more common on grasses.

Only four tests were made with this insect, in attempt to transfer the mottling disease, all of which were negative. (See Table VII.)

THE FALSE-MOTTLING LEAFHOPPER (not determined).

Like some other cane pests, this leafhopper lives more commonly on grasses, and seems to attack only very young canes. In the field it has been rarely observed, probably because of its small size, inconspicuous coloring, and its agility. The nymphs are very pale, almost white in color, and live near the tips of the leaves on sugar-cane, though on grasses they may occur anywhere on the undersides of leaves.

In common with the black thrips, this insect made its appearance on young cane plants during February, and in March became very common, but by April adults were again scarce. A second generation appeared in May and June, and what is believed to be a third generation in August. Cane leaves showing attack become streaked

with long white marks, from the extraction of the chlorophyll, in a manner very suggestive of the mottling disease. From this the insect receives its common name, false-mottling leafhopper.

Only five tests, of their ability to transmit mottling diseases, were made with this leafhopper, all of which gave negative results. (See Table VII.)

THE CANE SEED-HEAD LEAFHOPPER (*Balclutha* sp.).

This is a small leafhopper of the general shape of *Kolla similis* Walk., but only two-thirds its size and varying from pale green to yellowish-brown in color. In December and January it occurred in the greatest abundance in the seed tassels of such cane plants as bore seed, and is believed to have been a principal cause of the low fertility of the seed. For this reason it may be a serious retarding factor in production of new cane varieties. The nymphs, which are dark in color with lighter dorsal stripe, could be shaken by thousands from a single cane seed tassel. They were heavily preyed upon by larvae of a Syrphid fly.

Through the summer, when no cane is seeding, this leafhopper thrives in great abundance on the seed-heads of common pasture grass, or ''malojillo'' (*Eriochloa subglabra*), where it is heavily parasitized by a black, ant-like Dryinid wasp (*Chalcogonatopus* sp.), and by a fungus that seems to follow attack of the parasite larva.

These leafhoppers come in abundance to electric light, and might be controlled by means of trap lights. As they do not appear to attack sugar cane except rarely when it is not in seed, it is unlikely that they can be a factor in transmission of the mottling disease. Five tests were made with the species (two of them by method B), all giving negative results. (See Table VII.)

THE SUGAR-CANE RED-SPIDER (*Oligonychus viridis?*)

This very small mite is barely visible to the naked eye because of its size and protective coloration. It lives and reproduces on the cane foliage, usually on underside along the midrib, sometimes spinning a fine web over the infested portions of leaf, and by sucking the chlorophyll from the leaf it causes a white blotching or streaking that might be mistaken for mottling by one unfamiliar with the disease. The adult insect has eight legs and is a very small spider, pale greenish or yellowish in color with dark markings at the sides. It differs only in feeding habits and microscopic details from some

other common species of red-spider, and is a species capable of rapid multiplication.

Because of its minute size, this mite has been difficult to keep out of experimental cages containing other insects; and if it be proved to transmit the disease, it can have been responsible for apparent transmissions by other insects, since any portion of leaf bearing insects that is dropped into a cage to infest a plant, or plants, will unavoidably harbor young or eggs of red-spider. The six tests made using red-spider alone gave negative results. (See Table VII.)

TABLE VII.

EXPERIMENTS WITH *SIPHA FLAVA* FORBES.

Plant Numbers	Plants Subjected to Insects	Control Plants	Date of Confining Insects	Insects Confined per Plant	Days Insects were confined	Date Plant put into Field	Test Plants Became Mottled	Number of Mottled Test Plant	Date Mottling Appeared	Controls Became Mottled	Number of Control	Date Control Became Mottled
353	1	0	3-19	1 adult..................	......	(Died)	......	......	......	......	......	......
412-417.	6	1	4-26	20+ adults and young	34(c)	8-11	None	......	......	None	......	......
418-419.	2	1	4-26	12+ " " "	34(c)	8-11	"	......	......	"	......	......
523-532.	12	3(a)	9-29	100+ " " "	16(c)	10-15	One	531	10-9	One	531	1-26
Total	21	5	Plants became diseased				One test plant			One control (d)		

EXPERIMENTS WITH *PULVINARIA ICERYI* (GUER.).

423-426.	4	0	4-28	5-10 scales..............	(c)	8-11	One	426	5-31	......	.....	......
550-552.	3	3(a)	10-10	10+ "	(c)	10-17	None	......	......	None	......	......
593-594.	2	2(b)	10-23	12+ "	(c)	11-12	"	......	......	"	......	......
605-607.	3	3(b)	10-30	10+ "	(c)	11-12	"	......	......	"	......	......
660-661.	2	2([illegible])	11-30	15+ "	(c)	2-16	"	......	......	"	......	......
Total	14	10	Plants became diseased				One test plant			No control		

EXPERIMENTS WITH THE YELLOW CANE THRIPS.

163-174.	12	2	1-10	8+ adults..............	24+	2-3	None	......	.....	None	......	......
178-182.	5	1	1-10	8+ "	36+	2-15	"	......	......	"	......	......
Total	17	3	Plants became diseased				No test plant			No control		

EXPERIMENTS WITH THE BLACK CANE THRIPS.

467	1	0	5-28	18 adults...............	(c)	8-12	None	......	......	......	......	......
484-486.	3	1	5-30	15+ adults..............	(c)	8-13	"	......	......	None	......	......
Total	4	1	Plants became diseased				No test plant			No control		

TABLE VII—Continued.

EXPERIMENTS WITH THE FALSE-MOTTLING LEAFHOPPER.

Plant Numbers	Plants Subjected to Insects	Control Plants	Date of Confining Insects	Insects Confined per Plant	Days Insects were Confined	Date Plant put into Field	Plants Became Mottled	Number of Mottled Plant	Date Mottling Appeared	Controls Became Mottled	Number of Controls	Date Control Became Mottled
348.....	1	1	3-17	8 adults	(c)	6-2	None	......	......	None	......	......
360.....	1	1	3-31	4 nymphs	24	6-2	"	......	......	"	......	......
374.....	1	1	3-31	2 adults	30	6-2	"	......	......	"	......	......
464.....	1	1	5-27	1 nymph.................	(c)	8-12	"	......	......	"	......	......
487.....	1	1	6-2	2 adults and 1 nymph..	(c)	8-13	"	......		"	......	......
Total	5	5	Plants became diseased				No test plants			No controls		

EXPERIMENTS WITH THE CANE SEED-HEAD LEAFHOPPER.

Plant Numbers	Plants Subjected to Insects	Control Plants	Date of Confining Insects	Insects Confined per Plant	Days Insects were Confined	Date Plant put into Field	Plants Became Mottled	Number of Mottled Plant	Date Mottling Appeared	Controls Became Mottled	Number of Controls	Date Control Became Mottled
273.....	1(e)	1	2-19	100 adults	(c)	....	None	......	......	None	......	......
282.....	1(e)	0	2-19	100 adults	(c)	....	"	......	......	......	......	......
313.....	1	1	3-14	1 adult..................	(c)	6-2	"	......	......	None	......	......
405.....	1	1	4-25	1 adult............ ...	(c)	8-12	"	......	......	"	......	......
Total	4	3	Plants became diseased				No test plants			No checks		

EXPERIMENTS WITH THE SUGAR-CANE RED-SPIDER.

Plant Numbers	Plants Subjected to Insects	Control Plants	Date of Confining Insects	Insects Confined per Plant	Days Insects were Confined	Date Plant put into Field	Plants Became Mottled	Number of Mottled Plant	Date Mottling Appeared	Controls Became Mottled	Number of Controls	Date Control Became Mottled
447-452.	6	2	4-30	All stages (f)...........	(c)	8-5	None	......	......	None	.....	......

(a) Control plants of style *b* used.
(b) Control plants of style *c* used.
(c) Insects not removed from cane plant before it was transplanted to field.
(d) This control plant undoubtedly became diseased by inadvertent secondary infection.
(e) Mottled and healthy plant in same cage, method A.
(f) A portion of mottled cane leaf containing all stages of the red-spider dropped into cage with plant.

EXPERIMENTS WITH CHEWING INSECTS.

As explained in a previous paragraph, the possibility of mottling disease being transmitted by any species of chewing insect seems so remote that very little experimntal effort has been expended along this line of investigation.

The insect that has received most attention is the cone-headed katydid (*Neoconocephalus mexicanus* Sauss.). Seven test plants were employed, one with adults and six by using nymphs. The latter were transferred successively from mottled to healthy plants several times, in close succession, but the healthy plants eaten as result of these transfers gave no later indications of mottling. (See Table VII.)

With the common field grasshopper (*Schistocerca columbina*

Thunb.) and the dusky ground grasshopper (*Sphingonotus haitensis* Sauss.) two tests each were made, all proving negative.

A test each was made with the changa (*Scapteriscus vicinus* Scud.), the spider-legged cricket (*Amphiacustes annulipes* Sauss.) and a common roach (undetermined), in each case the insects being introduced into a small cage with young healthy cane after confinement for a week or more with mottled cane. All gave negative results. (See Table VII.)

A test each was made with the two common May-beetles of the north coast (*Phyllophaga portoricensis* Smyth and *P. citri* Smyth), adults in each case being introduced in numbers into a cage containing young mottled and healthy cane plants mixed. No healthy plants became mottled as result, within a space of six months, when plants were uprooted.

A test each was made with the three following arthropods, using the same method as that used with the crickets and roaches: sowbugs (*Porcellio* sp.), the flat greenhouse milliped (*Parajulus* sp.), and young of the common bush milliped (*Rhinocricus arboreus* Sauss.). All gave negative results.

TABLE VIII.

EXPERIMENTS WITH CHEWING INSECTS.

Species of insects	Plants subjected to attack	Control plants	Date of confinement	Insects per plant	Days confined	Results
Neoconocephalus mexicanus	1	1	Jan. 10	1 adult	16	Negative
" "	1	0	" 10	1 nymph	10	"
" "	1	1	Feb. 17	10 nymphs	4	"
" "	1	1	" 21	1 nymph	17	"
" "	1	0	" 21	1 "	17	"
" "	1	1	Mar. 14	1 "	17	"
" "	1	0	" 14	1 "	17	"
Schistocerca columbina	1	1	Jan 10	1 adult	20	"
" "	1	1	Oct. 23	2 nymphs	7	"
Sphingonotus haitensis	1	1	Jan. 10	1 adult	4	"
" "	1	0	" 10	1 "	10	"
Amphiacustes annulipes	1	1	Oct. 10	3 nymphs	7	"
Scapteriscus vicinus	1	1	" 23	1 adult	**	"
Roach (*Blatta* sp.)	1	1	" 24	3 nymphs	19	"
Sow-bug (*Porcellio* sp.)	1	1	" 24	11 adults	19	"
Milliped (*Parajulus* sp.)	1	1	" 10	6 "	7	"
Milliped (*Rhinocricus arboreus*)	1	1	" 23	15 young	**	"
Phyllophaga portoricensis	2*	0	May 29	10 adults	**	"
Phyllophaga citri	2*	0	" 29	10 "	**	"
Total number of plants	21	13	All results negative			

* The May-beetles were introduced into outdoor cages containing both mottled and healthy cane, according to method A.

** Insects were not removed from these plants up to the time plants were transplanted to the field.

Summary.

1. Failure of other and ordinary means of dispersion of plant diseases to account for the rapid spread of the cane mottling disease, under normal conditions, has led to a belief that the disease may be carried by insects.

2. Until substantial proof has been given that the cane mottling disease results from an organism capable of bearing fructifications or forming spores, there seems better reason to suspect sucking than chewing insects of transmitting the disease.

3. Field observations have thrown little light on the problem of insect transmission of mottling disease, the only insect yet observed which might satisfy all conditions, on the South Coast at least, being the yellow cane thrips (*Frankliniella* sp.).

4. It is believed that secondary infection with mottling disease, in a field planted to healthy seed, might occur from slow-moving insects like the mealybug or rust-mite, that could harbor over in numbers on stubble, volunteer cane or grass from a previous infected crop. This renders important the clean cultivation of cane fields between crops. These pests cannot, however, account for wide and rapid spread of mottling disease among plants grown from healthy seed and planted in new ground.

5. From the large number of experimental tests made in insect transmission, only four successful inoculations resulted. These four were all from different species of insects; but it is unique that all resulted from sucking insects. One of these was the West Indian cane-fly, a second the cane leaf scale, a third the yellow cane aphis, and a fourth the mealybug. (See foot note on page 83.)

6. No successful inoculations of mottling disease resulted from experimental tests with chewing insects. The number of such tests made was, however, not large.

7. In view of the small number of successful inoculations secured, as compared with the rather large number of tests made, under conditions which were considered favorable, the question of insect transmission of cane mottling disease cannot be looked upon as settled. Factors not visible to the investigator may have entered into the success of the inoculations, other than the factor of insect attack.

8. Future attempts will be made to duplicate inoculations which have thus far been secured from apparent insect transmission. It is significant, however, that in our experiments as thus far made

no control plants have become diseased (except by what was very evidently later secondary infection).

9. It is not improbable that, in common with certain other similar diseases of plants, inoculation of a healthy cane plant with mottling disease requires that the plant be in a condition of rapid growth. As our potted cane test-plants were not always in a condition of rapid growth at time that insects were introduced with plants, this may have acted as an inhibitive factor in the success of the inoculations.

10. The question of the infective principle of the disease being carried by the insect for some length of time, and undergoing a cyclic change within the insect body, or of its being transmitted to the young through the egg, before it becomes pathogenic to the plant host through the medium of the insect's bite, is yet to be investigated.

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Discusses use of Hawaiian beetle fungus against May-beetles (pp. 23–24), and of other fungi against cane pests.

(58) 1913. Jones, T. H.
Some Notes on *Laphygma frugiperda* S. & A. in Porto Rico. *In* Jl. Econ. Ent., Vol. 6, No. 2, April, 1913, pp. 230–236.
Discusses this species and *Remigia repanda* Fab. as cane pests.

(59) 1913. Quaintance, A. L.
Remarks on Some of the Injurious Insects of Other Countries. *In* Proc. Ent. Soc. Washington, Vol. 15, No. 2, June 10, 1913, pp. 54–83.
Mentions from P. R.: *Scapteriscus didactylus* Latr. (p. 57), *Pseudococcus sacchari* Ckll. (p. 63), and *Lachnosterna* spp. (pp. 76–77).

(60) 1913. Tower, W. V.
Rept. of the Entomologist's Inspection Trip to Santo Domingo. *In* 2nd. Rept., Board Comm. Agr. of P. R., 1912–1913, pp. 25–28.
Supposed identity of several Santo Domingo cane pests with those of Porto Rico.

(61) 1913. Van Dine, D. L.
The Insects Affecting Sugar Cane in Porto Rico. *In* Jl. Econ. Ent., Vol. 6, No. 2, April, 1913, pp. 251–257.
Resumé of all published information on cane insects of P. R. to that date, with discussion and original observations on each pest.

(62) 1913. VAN DINE, D. L.
The Introduction of Parasites of May-beetles into Porto Rico. *In* Second Rept. Board Comm. Agr. of P. R. for 1912–1913. San Juan. June 30, 1913. pp. 36–48.
Introduction of *Tiphia inornata* cocoons from Illinois (including tables).

(63) 1913. VAN DINE, D. L.
Report of the Entomologist. *In* 3rd. Ann. Rept. Exp. Sta., P. R. S. P. A., Río Piedras, Aug. 1913. pp. 25–46.
List and bibliography of sugar-cane pests in Porto Rico: also account of the rhinoceros beetle and the weevil root-borer.

(64) 1913. VAN DINE, D. L.
Insects Injurious to Sugar-Cane in Porto Rico, and Their Natural Enemies. *In* Jl. Board Agr., Brit. Guiana, Vol. 6, No. 4, pp. 199–203.

(65) 1913. WALTON, W. R.
New North American Tachinidæ (Diptera). *In* Entomological News, Vol. 24, No. 2, Feb., 1913, pp. 49–52, pl. 1.
Description of *Eutrixoides jonesii* gen. et sp. nov., from Porto Rico, reared from *Lachnosterna* (pp. 50–51).

(66) 1913. WOLCOTT, GEORGE N.
Report on a Trip to Demerara, Trinidad and Barbados During the Winter of 1913. *In* 3d Ann. Rept. (Bul. 5), Exp. Sta. P. R. S. P. A., Río Piedras, Aug. 1913, pp. 47–68.
Compares cane pests of these countries with those of Porto Rico.

(67) 1913. WOLCOTT, GEORGE N.
Report on a Trip to Demerara, Trinidad and Barbados During the Winter of 1913. *In* Jl. Econ. Ent., Vol. 6, No. 6 (Dec. 1913), pp. 443–457.
Extract of the preceding article.

(68) 1913. ——— ———.
Useful Birds of Porto Rico. *In* Porto Rico Progress, Vol. 4, No. 13, pp. 13–14. (Noted from Experiment Station Record, Vol. 28, No. 8, June 1913, p. 751.)
Several species of herons found by Biological Survey to destroy *changa*.

(69) 1913. ——— ———.
Destruction of Mole Crickets in Porto Rico by the Heron and Gaulding. *In* The Agricultural News, Barbados, Sept. 27, 1913, p. 314.
Review of article in Exp. Sta. Record for June, 1913.

(70) 1913. ——— ———.
An Entomological Visit to the United States. *In* The Agricultural News, Barbados, Oct. 25, 1913, p. 346.
Includes visit to P. R. and brief discussion of cane pests of the Island.

(71) 1914. BALLOU, H. A.
Insect Pests of Sugar Cane in Antigua and St. Kitts. Pamphlet Series No. 75, Imp. Dept. Agr. for W. I., Barbados, 1914, pp. 45, pl. 1, figs. 20.
Notes *Strategus titanus* (p. 43) and *Diaprepes spengleri* (pp. 41–43) as occurring in P. R.

(72) 1914. JONES, T. H.
Sugar-Cane Insects in Porto Rico. *In* Jl. Econ. Ent., Vol. 8, No. 6, Dec. 1914, pp. 461–463. (See Review Applied Ent., A, III, 3, March 1915, p. 134.)
Discusses known cane insect pests of the Island, including a number not before recorded (*Pseudococcus calceolariæ, Aphis setariæ, Prenes ares, Tetranychus* sp. and 2 species of thrips).

(73) 1914. LENG, CHAS. W., AND MUTCHLER, A. J.
A Preliminary List of the Coleoptera of the West Indies as Recorded to January 1, 1914. Bulletin of Am. Mus. Nat. Hist., Vol. 23, Art. 30, pp. 391–493, New York, Aug. 26, 1914.
Beetles known to attack cane listed from P. R. on pages 442, 454, 469, 478 and 480.

(74) 1914. PIERCE, W. DWIGHT.
Description of Two New Species of Strepsiptera (Halcotophagidæ) Parasitic on Sugar-Cane Insects. *In* Proc. Ent. Soc. Washington, XVI, 3, Sept. 1914, pp. 126–129.
Stenocranus saccharivorus parasitized by *Stenocranophilus quadratus* gen. et sp. nov. at Río Piedras, P. R., in Oct. 1912.

(75) 1914. VAN ZWALUWENBURG, R. H.
Preliminary Check List of Porto Rican Insects, Mayagüez, Sept. 1914, pp. 62. (Additions to same, March 1915, pp. 15.)
Mimeographed list distributed to friends and museums. Cane pests listed, under orders.

(76) 1914. WALTON, W. R.
Four New Species of Tachinidæ from North America. *In* Proc. Ent. Soc. Washington, XVI, 2, pp. 93–95. Washington, June 1914.
Describes two from P. R., *Linnemyia fulvicauda* from *Remigia repanda*, and *Compsilura oppugnator* from *Cirphis latiuscula*.

(77) 1914. WOLCOTT, GEORGE N.
Notes on the Life-History and Ecology of *Tiphia inornata*

Say. *In* Jl. Econ. Ent., Vol. 7, No. 5, Oct. 1914, pp 382–389.
Studies in connection with collection of cocoons for shipment to Porto Rico.

(78) 1914. ——— ———.
Termites or White Ants. *In* Agricultural News, Vol. 13 No. 309, Feb. 28, 1914, p. 74.
States that "the species of *Eutermes* are known to attack cane plants in the field in Antigua and Porto Rico," and lists *E. acagutlas* from P. R.

(79) 1915. Ballou, H. A.
Notes on Porto Rico Insects. *In* The Agr. News, Barbados, Aug. 28, 1915, p. 282.
Reviews Circular 6, P. R. Insular Exp. Sta., on "the *changa*".

(80) 1915. Crossman, S. S., and Wolcott, G. N.
Control of the Changa. Cir. 6, Insular Exp. Sta. of P. R. Río Piedras, 1915, pp. 3.
Recommends a bait of flour and Paris green.

(81) 1915. Fiske, R. J.
Report of the Quarantine Inspection Work. *In* 3d Rept., Board Comm., Agr. of P. R., 1913–1914, San Juan, 1915 pp. 14–19.
Mentions the fire ant (*Solenopsis geminata*) as "a very serious pest to the fruit, coffee, and sugar industry" (p. 19).

(82) 1915. Holloway, T. E.
Fighting the Sugar-Cane Borer with Parasites and Poisons. *In* The Louisiana Planter, Dec. 18, 1915, pp. 397-398.
Discusses the effects of trash burning and of rainfall on Diatræa in Porto Rico.

(85) 1915. Johnston, J. R.
Report of the Work of the Department of Pathology. *In* 3d Report, Board Comm. Agr. of Porto Rico, 1913–1914, San Juan, 1915, pp. 63–64.
Notes an experiment in the use of Green Muscardine fungus to control May-beetles.

(84) 1915. Johnston, John R.
The Entomogenous Fungi of Porto Rico. Bul. 10, Board Comm. Agr. of P. R., Río Piedras, Mar. 15, 1915, pp. 33, pls. 9.
Fungi attacking cane insects: *Agrostalagmus albus* (p. 10), *Aspergillus flavus* (pp. 14–18), *Botrytis rileyi* (pp. 18–19), *Isaria barberi* (pp. 20, 24–25), *Empusa sphærosperma* (pp. 22–23), *Isaria* sp. (pp. 25–26), and *Metarrhizium anisopliæ* (pp. 26–28).

(85) 1915. Jones, Thos. H.
Report of the Department of Entomology. *In* Third Report, Board Comm. Agr. of P. R., 1913–1914, San Juan, 1915, pp. 19–25.
Discusses work on May-beetles and their introduced parasites, and proposed work on other cane pests.

(86) 1915. Jones, T. H.
Aphides or Plant Lice Attacking Sugar-Cane in Porto Rico. Bul. 11, Exp. Sta. of Board Comm. Agr. of P. R., Mar. 15, 1915, pp. 19, pls. 2.
Life-history and habits of *Sipha flava* Forbes and *Aphis setariæ* Thos.

(87) 1915. Jones, T. H.
The Sugar-Cane Moth Stalk-Borer (*Diatræa saccharalis* Fabr.). Bul. 12, Exp. Sta. of Board Comm. Agr. of P. R., Río Piedras, Mar. 16, 1915, pp. 30, figs. 8.
Life-history, parasites, control, etc.

(88) 1915. Jones, Thomas H.
Insects affecting Vegetable Crops in Porto Rico. Bul. 192, U. S. D. A., Washington, Apr. 8, 1915, pp. 11, pls. 4.
Discusses *Scapteriscus didactylus* Latr. (p. 4), *Diabrotica graminea* Bal. (p. 5), *Laphygma fungiperda* S. & A. (p. 7), and *Solenopsis geminata* Fab. (p. 9) as vegetable pests.

(89) 1915. Jones, Thos. H.
The Sugar-Cane Weevil Root-Borer (*Diaprepes spengleri* L.). Bul. 14, Exp. Sta., Board Comm. Agr. of P. R., Río Piedras, Apr. 14, 1915, pp. 19, figs. 11.
Life-history, habits, parasites, control, etc.

(90) 1915. Pierce, W. Dwight.
Some Sugar-Cane Root-Boring Weevils of the West Indies. *In* Jl. Agr. Research, Vol. 4, No. 3, Washington, June 15, 1915, pp. 255–263, pls. 4.
Groups the forms of *Diaprepes* attacking sugar cane into 2 species, *famelicus* Oliv. and *spengleri* Linn., the latter of them having 6 varieties, 3 of which occur in Porto Rico. Gives briefly control measures.

(91) 1915. Smyth, E. G.
Report of Work at the South Coast Laboratory. *In* 3d. Report, Board Comm. Agr. of P. R., 1913–1914, San Juan, 1915, pp. 40–53.
Field habits and control of 3 species of *Lachnosterna*, 2 of *Dyscinetus*, 1 of *Ligyrus* and 1 of *Strategus* (cane pests), and release of *Tiphia* wasps from Illinois.

(92) 1915. Tower, W. V.
Report of the Secretary. *In* Third Report, Board Comm. Agr. of P. R., 1913–1914, San Juan, 1915, pp. 9–13.

Notes work "combating the *changa*" (p. 10), and of the traveling entomologist "obtaining parasites of the white-grub, *changa*, mealy-bug and moth-borer" (p. 11).

(93) 1915. VAN ZWALUWENBURG, R. H.
Report of the Entomologist. *In* Rept. P. R. Agr. Exp. Sta., U. S. D. A., for 1914, Mayagüez, July 10, 1915, pp. 31–35.
Discusses control of *Scapteriscus didactylus* (pp. 31–32), of May-beetles by a bacterium (p. 34), and gives note on *Diaprepes spengleri* (p. 35).

(94) 1915. WOLCOTT, G. N.
Report of the Traveling Entomologist. *In* 3d. Rept., Board Comm. Agr. of P. R., 1913–1914, San Juan, 1915, pp. 25–40.
Introduction of May-beetle parasites from Illinois and account of trips to Cuba and Jamaica to secure cane insect parasites.

(95) 1915. WOLCOTT, GEORGE N.
Influencia de la lluvia y la quemazón de la paja sobre la abundancia de *Diatræa saccharalis.* Cir. 7, Insular Exp. Sta. of P. R., Río Piedras, 1915, pp. 6.

(96) 1916. BALLOU, H. A.
Fighting the Sugar-Cane Borer with Parasites and Poisons. *In* The Agr. News, Barbados, Apr. 22, 1916, pp. 138–139.
Reviews article by Holloway in Louisiana Planter, Dec. 18, 1915. Mentions effects of rainfall on Diatræa in P. R.

(97) 1916. MARSHALL, G. A. K.
On New Neotropical Curculionidæ. *In* Ann. and Mag. Nat. Hist., Vol. 18, No. 108, London, Dec. 1916, pp. 449–468.
Discusses the synonymy of species and varieties of *Diaprepes* characterized by Pierce (Jl. Agr. Research, June 15, 1915).

(98) 1916. MERRILL, G. B.
Report of the Tobacco Insect Investigations. *In* 4th Report, Board Comm. Agr. of P. R., 1914–1915, San Juan, 1916, pp. 50–52.
Discusses control of *changa* (pp. 50–51).

(99) 1916. SMYTH, E. G.
Report of the South Coast Laboratory. *In* 4th Report, Board Comm. Agr. of P. R., 1914–1915, San Juan, 1916, pp. 45–50.
Account of experimental work on white grubs, and table of life-history summaries of 8 species of Scarabæidæ, attacking cane.

(100) 1916. STEVENSON, JOHN A.
Report of the Pathologist. *In* 4th Report, Board Comm. Agr. of P. R., 1914–1915, San Juan, 1916, pp. 33–44.
Work with the Green Muscardine (pp. 34–35).

(101) 1916. TOWER, W. V.
Report of the Secretary and Director. *In* 4th Report, Board Comm. Agr. of P. R., 1914–1915, San Juan, 1916, pp. 9–16.
Notes briefly (p. 11) the year's work on cane pests and *changa*.

(102) 1916. VAN ZWALUWENBURG, R. H.
Report of the Entomologist. *In* Rept. P. R. Agr. Exp. Sta., U. S. D. A., for 1915, Mayagüez, Nov. 23, 1916, pp. 42–45.
Discusses *Scapteriscus didactylus* (p. 42), *Eutermes morio* as a timber pest (p. 43), *Strategus quadrifoveatus* as a coconut pest (p. 44), *Apate francisca* as a mahogany pest (p. 44), and *Sipha flava* on cane (p. 45).

(103) 1916. WETMORE, ALEX.
Birds of Porto Rico. Bul. 326, Bu. Biol. Sur., U. S. D. A., 1916, pp. 140, pls. 10. (= Bul. 15, P. R. Insular Exp. Sta.)
Gives stomach contents of majority of P. R. birds, enumerating cane pests.

(104) 1916. WOLCOTT, GEORGE N.
Report of the Entomologist. *In* 4th Report, Board Comm. Agr. of P. R., 1914–1915, San Juan, 1916, pp. 17–22.
Gives summary of bulletins 11, 12 and 14, dealing with cane pests, by T. H. Jones.

(105) 1916. ———————.
The Birds of Porto Rico. *In* the Agricultural News, Barbados, July 1, 1916, p. 219.
Review of Bulletin 326, U. S. D. A., by Alex Wetmore; discusses bird enemies of cane insects in P. R.

(106) 1917. HUTSON, J. C.
Some Weevils of the genus Diaprepes in the West Indies. *In* The Agricultural News, Barbados, June 16, 1917, p. 186.
Gives table and distribution of species recently determined by Dr. Pierce.

(107) 1917. HUTSON, J. C.
White Grubs Injuring Sugar-Cane in Porto Rico. *In* The Agricultural News, Barbados, July 14 (pp. 218–219), July 28 (p. 234), and Aug. 11, 1917 (pp. 250–251).
Review and discussion of article of same title by Smyth in Jl. Dept. Agr. of P. R., Vol. 1, No. 2, pp. 47–92.

(108) 1917. HUTSON, J. C.
Sugar-Cane White Grubs in Porto Rico. *In* The Agricultural News, Barbados, Oct. 20, 1917, pp. 330–331.
Review and discussion of article on white-grubs by Smyth in Jour. Dept. Agr. of P. R., Vol. 1, No. 3, pp. 141–169.

(109) 1917. JONES, T. H.
A List of the Coccidæ of Porto Rico. *In* Jl. of Board Comm. Agr. of P. R., Vol. 1, No. 1, Jan. 1917, pp. 1–16.
Lists *Pseudococcus calceolariæ* Mask. (p. 4), Ps. *sacchari* Ckll. (p. 5), *Aclerda tokionis* Ckll. (p. 8) and *Aspidiotus sacchari* Ckll. (p. 12) as cane pests.

(110) 1917. SMYTH, E. G.
The White-Grubs Injuring Sugar-Cane in Porto Rico, Part I. Melolonthids. *In* Jl. Dept. Agr. of P. R., Vol. 1, No. 2, Apr. 1917, pp. 47–92, pls. 8, and Vol. 1, No. 3, July 1917, pp. 141–169.
Researches into the life-history, damage, distribution, parasites, etc., of 4 new species of *Phyllophaga* (=*Lachnosterna*) and 1 new species of *Phytalus*.

(111) 1917. SMYTH, E. G.
The White-Grubs Injuring Cane and Other Crops in Porto Rico. *In* Porto Rico Progress, San Juan, May 18, 1917.
Popular account of their injuries and life-histories.

(112) 1917. SMYTH, E. G.
Report of the Entomological Department. *In* Ann. Rept. Insular Exp. Sta. of P. R., 1916–1917, Río Piedras, 1917, pp. 99–106.
Account of cane insects intercepted from Santo Domingo, and of fumigation of cane steamers (pp. 105–106).

(113) 1917. STEVENSON, J. A.
Report of the Pathologist. *In* 5th Report, Board Comm. Agr. of P. R., 1915–1916, San Juan, 1917, pp. 35–74.
States (p. 68) that moth stalk-borer larvæ pass through uninjured when cane trash is burned.

(114) 1917. STEVENSON, JOHN A.
Report of the Department of Pathology and Botany. *In* Ann. Rept., Insular Exp. Sta. of P. R., 1916–1917, Río Piedras, 1917, pp. 37–98.
Notes (p. 56) injury to cane experiments by *Diatræa*, *Diaprepes spengleri* and *Phyllophaga* spp.

(115) 1917. TOWER, W. V.
Report of the Director. *In* 5th Report, Board Comm. Agr. of P. R., 1915–1916, San Juan, 1917, pp. 9–15.
Notes briefly work on *Diatræa saccharalis* (p. 14) and on *changa* (p. 15).

(116) 1917. Van Zwaluwenburg, R. H.
Insects Affecting Coffee in Porto Rico. *In* Jl. Econ. Ent., Vol. 10, No. 6, Dec. 1917, pp. 513–517.
Discusses: *Apate fransisca* Fab. (p. 516) and the May-beetles and their two Tachinid parasites (p. 517).

(117) 1917. Wolcott, G. N
Report of the Entomologist. *In* 5th Report, Board Comm. Agr. of P. R., 1915–1916, San Juan, 1917, pp. 75–85, pl. 1.
Effect of rainfall and trash burning upon infestation of cane by *Diatræa saccharalis* (pp. 80–85).

(118) 1918. Cotton, R. T.
Experimental Work on the Control of the White Grubs of Porto Rico. *In* Jl. Dept. Agr. of P. R., Vol. 2, No. 1, Jan. 1918, pp. 1–18.
Deals with the larvæ of *Phyllophaga,* mainly as sugar-cane pests. Summarizes work of other investigators.

(119) 1918. Cotton, R. T.
Medios para Combatir los Gusanos Blancos. Cir. 12, Insular Exp. Sta. of P. R., Río Piedras, 1918, pp. 7.
Control measures for white-grubs.

(120) 1918. Cotton, R. T.
Insects Attacking Vegetables in Porto Rico. *In* Jl. Dept. Agr. of P. R., Vol. 2, No. 3, Oct. 1918, pp. 265–317, figs. 67.
Discusses: *Changa* (p. 270), grasshoppers (p. 272), white-grubs (p. 274), *Laphygma frugiperda* (p. 288), *Diatræa saccharalis* (p. 290), fire ant (p. 296), and *Diabrotica graminea* (p. 302).

(121) 1918. Hutson, J. C.
The Production of Light in Certain Animals. *In* The Agricultural News, Barbados, Jan. 12, 1918, pp. 10–11.
Mentions larvæ of *Pyrophorus luminosus* as predacious on white-grubs in cane fields in P. R.

(122) 1918. Hutson, J. C.
The West Indian Mole Cricket or *Changa.* *In* The Agricultural News, Barbados, Apr. 6, 1918 (pp. 106–107, fig. 1), and Apr. 20, 1918 (p. 122).
Review and discussion of Bul. 23, P. R. Agr. Exp. Sta., U. S. D. A.

(123) 1918. Stevenson, J. A.
The Green Muscardine Fungus in Porto Rico. *In* Jl. Dept. Agr. of P. R., Vol. 2, No. 1, Jan. 1918, pp. 19–32, pl. 1.
Twenty-one out of 29 recorded insect hosts are cane pests.

(124) 1918. Stevenson, J. A.
A Check List of Porto Rican Fungi and a Host Index. *In*

Jl. Dept. Agr. of P. R., Vol. 2, No. 3, July 1918, pp. 125–264.
Fungi attacking cane insects, pp. 134, 207, 208 and 218.

(125) 1918. Van Zwaluwenburg, R. H.
Report of the Entomologist. *In* Rept., P. R. Agr. Exp. Sta., U. S. D. A., for 1916, Mayagüez, Feb. 5, 1918, pp. 25–28, pl. 1.
Discusses light trapping of May-beetles (pp. 25, 26), *Scapteriscus vicinus* (p. 25), and *Sipha flava* (p. 28). States that termite previously reported as *Eutermes morio* is *Cryptotermes* sp.

(126) 1918. Van Zwaluwenburg, R. H.
The Changa or West Indian Mole Cricket. Bul. 23, P. R. Agr. Exp. Sta., U. S. D. A., Mayagüez, Feb. 12, 1918, pp. 28, pls. 3.
Considered "the most serious insect pest of general agriculture in Porto Rico." Bibliography of 54 titles appended.

(127) 1918. Van Zwaluwenburg, R. H.
Some Means of Controlling Insects, Fungi, and Other Pests in Porto Rico. Cir. 17, P. R. Agr. Exp. Sta., U. S. D. A., Mayagüez, June 27, 1918, pp. 30.
Includes special control measures for cut-worms, *changa,* fire-ant, etc.

(128) 1918. Van Zwaluwenburg, R. H.
Report of the Entomologist. *In* Rept. P. R. Agr. Exp. Sta., U. S. D. A., for 1917, Mayagüez, Sept. 20, 1918, pp. 33–34.
Notes light trapping of *changas, Strategus quadrifoveatus* as a coconut pest, and tests of cyanamid as remedy for white grubs (p. 34).

(129) 1919. Ballou, H. A.
The Toad in the West Indies. *In* The Agricultural News, Barbados, Nov. 29, 1919, pp. 378–379.
Discusses the proposed introduction of toads into Porto Rico to combat white-grubs (see number 132, this list).

(130) 1919. Colón, E. D.
Report of the Director. *In* Ann. Rept., Insular Exp. Sta. of P. R. for June 30, 1918, Río Piedras, 1919, pp. 6–77.
Review of entomological work from 1913 to 1918, pp. 8–13; 29–59. Cane pests, pp. 8, 29–30, 32–33, 37–58.

(131) 1919. Holloway, T. E. and Loftin, U. C.
The Sugar-Cane Moth Borer. Bulletin No. 746, U. S. D. A., Washington, Apr. 18, 1919, pp. 74, pls. 10, figs. 12.

Mentions climatic and fungus control (pp. 35–38) and parasites (p. 41) of Diatræa in Porto Rico.

(132) 1919. SMYTH, E. GRAYWOOD.

Report of the Division of Entomology. *In* Ann. Rept., Insular Exp. Sta. of P. R. for June 30, 1918, Río Piedras, 1919, pp. 109–129.

Insect transmission of cane mottling disease (pp. 118–119), cane white-grub problem (pp. 119–120), hard-backs injuring cane (pp. 120–121), red-spider attacking cane (pp. 121–122), epidemic of yellow cane aphis (pp. 122–123), and *Eutermes morio* (pp. 126–127).

(133) 1919. SMYTH, E. GRAYWOOD.

Report of the Entomologist. *In* Ann. Rept., Insular Exp. Sta. of P. R. for year ending June 30, 1919, Río Piedras, 1919, pp. 27–31.

Work on the transmission of the sugar-cane mottling disease by insects, pp. 28–30.

(134) 1919. SMYTH, E. GRAYWOOD.*

[Work of the] Division of Entomology. *In* Report of the Commisioner of Agr. and Labor of P. R., Bureau of Insular Affairs, War Dept., Washington, 1919, pp. 685–713.

Mentions *Bothriocera* sp. as feeding on cane (p. 695), and discusses successful transmission of the cane mottling disease (p. 699) by means of *Stenocranus saccharivorus* Westw. and *Aclerda tokionis* Ckll. (the latter being a misdetermination for *Pulvinaria iceryi* Guer.).

(135) 1919. ——— ———.

Entomology in Porto Rico. *In* The Agricultural News, Barbados, Nov. 15, 1919, pp. 362–363.

Review of the entomologist's report (Ann. Rept. P. R. Insular Exp. Sta.) for year ending June 30, 1918.

(136) 1919. ——— ———.

Skunks and Toads—A Warning. *In* The Agricultural News, Barbados, Nov. 15, 1919, p. 361.

Discussion of proposed introduction of skunks and toads into P. R. to combat white-grubs.

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* The following paragraphs of this report: Plant Quarantine (pp. 691–692), Division of Entomology (p. 694), Work on Citrus Insect Pests (p. 695), and Entomological Work (on Yellow-Stripe Diseases) (p. 699), though not credited to the writer, are taken verbatim from his annual report, and were unfortunately omitted from the Annual Report of the Experiment Station for the same year.

LIST OF THE INSECT AND MITE PESTS OF SUGAR CANE IN PORTO RICO.[1]

By E. Graywood Smyth.

I. ACARINA.

1. *Oligonychus viridis?* (family Tetranychidæ).

   Common Name: Sugar-cane red-spider.
   Damage: Attacks leaves, especially undersides, causing white marks by extraction of chlorophyll.
   Distribution: Probably entire Island.
   Food Plants: Sugar cane and grasses.
   Enemies: A Cecidomyid fly; a Coccinellid and a Staphylinid beetle: and *Franklinothrips vespiformis.*
   Control: Dusting or spraying with sulphur mixtures; heavy infestation uncommon, hence spraying unnecessary.

2. *Uropodus* sp. (undetermined) (family Uropodidæ).
   Common Name: Sugar-cane root mite.
   Damage: Eats into, severs, and sometimes tunnels the roots. Damage sometimes serious.
   Distribution: North coast; possibly entire Island.
   Food Plants: Sugar cane; other hosts not observed.
   Enemies: None thus far recorded.
   Control: Crop rotation; maintenance of vigorous growth.

3. *Tarsonemus spinipes* Hirst (family Tarsonemidæ).
   Common Name: Sugar-cane rust mite.
   Damage: Forms flat, rusty-brown blisters on stem and leaf sheathes.
   Distribution: Entire Island; other West Indies.
   Food Plants: Sugar cane; no others known.
   Enemies: None recorded.
   Control: Dipping seed in lime-sulphur solution, or other strong disinfectant; clean cultivation between crops.

[1] This list includes all the insects that have been found repeatedly feeding upon the cane plant, *Saccharum officinarum*, though a considerable number of them have not been found breeding on cane. Lack of time has prevented the making or securing of accurate determinations in many cases. Distribution and food plants, of species occurring also in other localities, have been taken from such sources as were available. The author acknowledges having made free use of previous lists published by Messrs. Van Dine and Jones, former entomologists of this Station. There are twenty-six species in the present list which have not been previously recorded to the writer's knowledge as attacking sugar cane in Porto Rico.

The orders have been arranged according to Brues and Melander, the families according to Banks in the Acarina, Scudder in the Orthoptera, Blatchley and Leng in the Coleoptera, Dyer in the Lepidoptera, and Van Duzee in the Homoptera.

II. ORTHOPTERA.

4. *Schistocera pallens* Thunb. family Acrididæ).
Common Name: Larger field grasshopper.
Damage: Nymphs and adults attack foliage.
Distribution: South coast; other West Indies; South America.
Food Plants: Sugar cane, field crops, grass, etc.
Enemies: Animal—Birds; mangoose; lizards; tree frogs.
Arthropod—Tarantula; centipede; Bombyiid fly; certain wasps; a Cicindellid (*Tetracha*).
Fungus—Possibly *Botrytis rileyi.*
Control: Use of poison baits; night collection with lanterns; arsenical sprays on foliage where live stock do not have access.

5. *Schistocerca columbina* Brunn. (family Acrididæ).
Common Name: Common field grasshopper.
Damage: Attacks foliage, eating edges of leaves.
Distribution: Entire Island; other West Indies; Central and South America.
Food Plants: Sugar cane, grass, and many crops.
Enemies: Same as those of preceding species.
Control: Same as for preceding.

6. *Plectrotettix* (*Scyllina*) *gregarius* Walk. (fam. Acrididæ).
Common Name: Green-back grasshopper.
Damage: Attacks foliage; may become injurious when very abundant.
Distribution: Entire Island; St. Thomas; Haiti.
Food Plants: All tender green vegetation.
Enemies: The same as those of Schistocerca.
Control: By use of poison baits, or arsenical spraying.

7. *Sphingonotus haitensis* Sauss. (family Acrididæ).
Common Name: Dusky ground grasshopper.
Damage: Eats foliage, especially of young cane.
Distribution: Porto Rico; Haiti; Cuba; Mexico.
Food Plants: Any vegetation growing close to ground.
Enemies: Same as of those preceding.
Control: By use of poison baits.

8. *Neoconocephalus* (*Conocephalus*) *mexicanus* Sauss. (family Tettigoniidæ).
Common Name: Green cone-headed katydid.
Damage: Attacks foliage; splits leaf in laying eggs.
Distribution: Greater Antilles; southern U. S.; Mexico; Central and South America.
Food Plants: Sugar cane; grasses; many crops and trees.
Enemies: Animal—Mongoose; birds; lizards; tree frogs.
Arthropod—Centipede; large spiders; wasps.
Fungus—None recorded.
Control: Arsenical sprays; trap lights at night.

9. *Neoconocephalus cinereus* Thunb. (family Tettigoniidæ).
COMMON NAME: Brown cone-headed katydid.
DAMAGE: Both nymph and adult eat foliage.
DISTRIBUTION: Porto Rico; Jamaica.
FOOD PLANTS: Sugar cane and other vegetation.
ENEMIES: Same as those of *N. mexicanus.*
CONTROL: Arsenical sprays and trap lights.

10. *Microcentrum triangulatum* Brunn. (family Tettigoniidæ).
COMMON NAME: Broad-winged katydid.
DAMAGE: Eats the foliage; less common on cane than two preceding species.
DISTRIBUTION: Porto Rico; St. Thomas; Guadaloupe.
FOOD PLANTS: Sugar cane; citrus; many other crops.
ENEMIES: Same as those of preceding.
CONTROL: Arsenical sprays and trap lights.

11. *Cyrtoxiphus gundlachi* Sauss. (family Gryllidæ).
COMMON NAME: Little green tree-cricket.
DAMAGE: Always present on foliage; extent of injury not known. Eats the parenchyma of leaf, apparently.
DISTRIBUTION: Porto Rico; Cuba; Jamaica; southern U. S.; Mexico; St. Vincent; Nicaragua; Brazil.
FOOD PLANTS: Sugar cane; citrus; banana; most crops.
ENEMIES: Birds, lizards, tree-frogs, spiders and predacious bugs. No parasites yet recorded.
CONTROL: Amenable to contact sprays.

12. *Orocharis vaginalis* Sauss. (family Gryllidæ).
COMMON NAME: Brown tree-cricket.
DAMAGE: Conceals in terminal leaf coil and injures tender foliage.
DISTRIBUTION; Porto Rico; Santo Domingo; Cuba.
FOOD PLANTS: Sugar cane, citrus, and other crops.
ENEMIES: Same as of preceding species.
CONTROL: Light traps; arsenicals applied to foliage.

13. *Scapteriscus vicinus* Scud. (family Gryllotalpidæ).
COMMON NAME: *Changa,* or mole-cricket.
DAMAGE: Attacks roots and buds; damage very severe in sandy soils.
DISTRIBUTION: Greater and Lesser Antilles; south-eastern United States; Central and South America.
FOOD PLANTS: Sugar cane; lawn grass; all cultivated crops.
ENEMIES: Animal—Birds; lizards, especially the ground lizard, *Ameiva exul;* the mangoose.
Arthropod—Tarantula; centipede; the fire-ant; a wasp (Garrinæ); *Tetracha infuscata.*
Fungus—None known.
CONTROL: Poison baits (Paris green and flour; phosphorus and corn meal; white arsenic, molasses and dry manure); trap lights; protection of ground lizard; sprinkling ground with strong soap solution; planting cane with part of eyes above ground.

III. THYSANOPTERA.

14. *Frankliniella* sp. (family Thripidæ).

Common Name: Yellow cane thrips.

Damage: Works and breeds between coiled terminal leaves, scarifying leaf surface. Suspected of transmitting the mottling disease.

Distribution: Abundant on south coast, less so on north side of Island.

Food Plants: Sugar cane; possibly some wild grasses.

Enemies: Predacious bug, near Triphleps; probably also Coccinellids, and predacious thrips.

Control: Spraying with contact poisons; covering young plants, before attack, with bunting cloth; clean cultivation between crops.

15. *Haplothrips* (?) *tibialis* Hood. ? (family Thripidæ).

Common Name: Black cane thrips.

Damage: Works and breeds near tips of leaves of young cane, causing some spotting. Damage not severe.

Distribution: North coast, so far as recorded.

Food Plants: Sugar cane and grasses.

Enemies: *Franklinothrips vespiformis.*

Control: Not sufficiently injurious to require control.

16. *Podothrips semiflavus* Hood. (family Thripidæ?).

Common Name: Thrips.

Damage: Works between leaves; collected by T. H. Jones.

Distribution: Recorded from south coast of Island.

Food Plants: Sugar cane and Para grass.

Enemies: None recorded.

Control: Not required.

IV. ISOPTERA.

17. *Eutermes morio* Lath. (family Termitidæ).

Common Name: Termite, white-ant, or "comején."

Damage: Sometimes riddles the seed-cane in the soil. Rarely attacks standing cane.

Distribution: Entire Island.

Food Plants: Partly dry cane stalks; bark of trees; dead wood; timbers.

Enemies: Lizards; birds (eat the flying form); bats; no others observed.

Control: London purple or white arsenic powder on nest; kerosene; coal-tar creosote and kerosene; mercury bichlorid dissolved in water; white arsenic and washing soda boiled together, mixed with distillate; fumigation.

V. HYMENOPTERA.

18. *Solenopsis geminata* Fabr. (family Formicidæ).

Common Name: Fire-ant, or "hormiga brava."

DAMAGE: Injures cane indirectly by sheltering mealybugs and aphids from their enemies; also a menace to cane cutters. Causes lesions where fingi may enter.

DISTRIBUTION: Practically entire Western Hemisphere, in warmer climates.

FOOD PLANTS: No direct injury to cane, but injures citrus, cowpeas, egg-plants, banana trees, etc.

ENEMIES: None recorded.

CONTROL: Spraying with kerosene emulsion recommended; crop rotation and clean cultivation best means. London purple can be sprinkled on ant hills.

VI. COLEOPTERA.

19. *Apate francisca* Fab. (family Bostrychidæ).

COMMON NAME: Rough-headed stem borer.

DAMAGE: Riddles the standing stalks (rarely).

DISTRIBUTION: Entire Island.

FOOD PLANTS: Coffee, citrus, mahogany, flamboyant, chinaberry, *Salix humboldtiana,* Casuariana, Picramnia, Prosopis, gandule bean and sugar cane.

ENEMIES: Birds and lizards; no insect enemies recorded.

CONTROL: Drop carbon bisulphide into burrow and plug entrance; extirpate and burn infested plants.

20. *Phyllophaga vandinei* Smyth (Scarabæidæ).

COMMON NAME: Sugar-cane white-grub (May beetle; "caculo").

DAMAGE: Larvæ eat roots to great extent; costs one sugar "central" over a thousand dollars per annum to control.

DISTRIBUTION: Western third of Island.

FOOD PLANTS: Grubs eat all roots; adults nearly all foliage.

ENEMIES: Animal—Blackbirds; other birds; mongoose; the larger lizards; chickens; hogs; rats and mice.
Arthropod—Centipede; tarantula; larger spiders; *changa* (of eggs and larva); Scoliid wasps(?); larva of Pyrophorus; 2 Tachinid flies.
Fungus—*Metarrhizium anisopliæ.*
Bacterial—*Micrococcus nigrofaciens.*

CONTROL: Night collection of adults from foliage, or by shaking from trees and bushes onto sheets, and collection of grubs at plowing; protection of blackbirds by banding palm trees against rats; introduction of toads and skunks.

21. *Phyllophaga portoricensis* Smyth (family Scarabæidæ).

COMMON NAME: Common white-grub.

DAMAGE: Grubs attack the roots; adults do injury to foliage when abundant.

DISTRIBUTION: Eastern two-thirds of Island; Vieques.

FOOD PLANTS: Roots of all crops; foliage of many plants, especially flamboyant, palms, and banana trees.
ENEMIES: The same as those of *P. vandinei.*
CONTROL: Same as for preceding species.

22. *Phyllophaga guanicana* Smyth (family Scarabæidæ).
COMMON NAME: Guánica white-grub.
DAMAGE: Grubs attack roots, adults foliage. Not so injurious as *P. vandinei.*
DISTRIBUTION: Guánica district of the Island.
FOOD PLANTS: Grubs attack all roots, indifferently; adults prefer foliage of certain trees.
ENEMIES: The same as those of *P. vandinei.*
CONTROL: Same as for preceding species.

23. *Phyllophaga citri* Smyth (family Scarabæidæ).
COMMON NAME: Citrus white-grub.
DAMAGE: Grubs attack roots of all crops; adults eat foliage.
DISTRIBUTION: Entire Island except southwest corner; also Vieques.
FOOD PLANTS: Grubs eat roots of all crops; adults prefer foliage of citrus, guava, Acalypha, young palms, and Malvaceæ.
ENEMIES: The same as those of *P. vandinei.*

24. *Phytalus insularis* Smyth (family Scarabæidæ).
COMMON NAME: Little brown May-beetle.
DAMAGE: Attacks cane roots, but seldom to injurious extent.
DISTRIBUTION: Entire Island.
FOOD PLANTS: Grubs probably eat all roots; adults prefer foliage of grass, corn, Lantana, amaranth, and certain shrubs.
ENEMIES: Animal—Same as those of *P. vandinei.*
Arthropod—Same as preceding, with exception of Tachinid flies.
Fungus and bacterial—Same as of Phyllophaga.

25. *Dyscinetus* (*Chalepus*) *trachypygus* Burm. (family Scarabæidæ).
COMMON NAME: Dull black hard-back (in U. S.; the rice grub).
DAMAGE: Adults injure seed-cane and buds; larvæ bore into underground stalks.
DISTRIBUTION: Greater Antilles; southeastern United States.
FOOD PLANTS: Sugar cane, grasses, and root crops.
ENEMIES: Same as those of May-beetle, except Tachinid flies.
CONTROL: Trap lights; poison baits; clean cultivation.

26 *Dyscinetus barbatus* Fabr. (family Scarabæidæ).
COMMON NAME: Shining black hard-back.
DAMAGE: Adults and larvæ injure the underground stems, when abundant.
DISTRIBUTION: Porto Rico; possibly other Greater Antilles; Barbuda; St. Kitts.

FOOD PLANTS: Sugar cane, grasses and root crops.
ENEMIES: Animal—Same as those of Phyllophaga.
Arthropod—Centipede; tarantula; larger spiders; *changa* (of eggs and larvæ); larva of *Pyrophorus luminosus;* possibly Scoliid wasps.
Fungus—*Metarrhizium anisopliæ.*
CONTROL: Trap lights; poison baits; clean cultivation and deep plowing; cultivation of grass land.

27. *Ligyrus tumulosus* Burm. (family Scarabæidæ).
COMMON NAME: Brown hard-back.
DAMAGE: Adults injure stem and buds at surface of ground; larvæ bore underground stems.
DISTRIBUTION: Greater Antilles: St. Vincent; Nevis; Guadaloupe; St. Bartholomew; Barbados; Trinidad.
FOOD PLANTS: Sugar cane; grasses; root crops; breeds in decaying organic matter.
ENEMIES: Animal—Birds; bats; mongoose; larger lizards; poultry; hogs; rats and mice.
Arthropod—Centipede and tarantula; larger spiders; *changa; Pyrophorus luminosus; Campsomeris dorsata.*
Fungus—*Metarrhizium anisopliæ.*
CONTROL: Poisoned green manure plowed under; poisoned mash baits; trap lights; avoidance of organic fertilizers; destruction of grubs in manure heaps; frequent and deep cultivation.

28. *Strategus quadrifoveatus* Beauv. (family Scarabæidæ).
COMMON NAME: Coconut rhinoceros beetle.
DAMAGE: Adults occasionally tunnel stems of standing cane, to such extent that the cane falls over.
DISTRIBUTION: Porto Rico; Santo Domingo; Haiti.
FOOD PLANTS: Adults feed on sugar cane and young palms; larvæ mature in rotting wood.
ENEMIES: Animal—Herons; owls; mongoose; hogs and poultry; rats.
Arthropod—None thus far recorded.
Fungus—Green Muscardine fungus.
CONTROL: Collection in evening by boys with nets; light traps; trash (dead wood) traps for grubs; use of Green Muscardine in trash traps: poison bait.

29. *Strategus titanus* Fabr. (family Scarabæidæ).
COMMOON NAME: Sugar-cane rhinoceros beetle.
DAMAG5: Larvæ bore in "cepas" (underground stems) and decrease sap flow.
DISTRIBUTION: Porto Rico; Jamaica; Cuba; Vieques; Virgin Islands.
FOOD PLANTS: Larvæ eat cane stalks, also rotting wood.
ENEMIES: The same as those of *S. quadrifoveatus.*
CONTROL: Same as for preceding species.

30. *Diabrotica graminea* Balz. (family Chrysomelidæ).
Common Name: Green flower-beetle.
Damage: Adults feed to some extent upon the foliage, and larvæ upon the roots.
Distribution: Entire Island.
Food Plants: Flowers and foliage of many plants, including most vegetables as well as sugar cane.
Enemies: Animal—Birds; lizards; tree-frogs.
Arthropod—Spiders; ants; predacious bugs; *changa* (eats the larvæ).
Fungus—None recorded.
Controe: Spraying trap crops with arsenicals; sweeping foliage with nets or with tarred frames; shaking beetles from trap crops like okra or Cleome.

31. *Diaprepes spengleri* Linn. (family Curculionidæ).
Common Name: Sugar-cane root-weevil.
Damage: Larvæ bore large roots and bases of stalks; adults eat foliage to some extent.
Distribution: Porto Rico; Vieques.
Food Plants: Sugar cane, citrus, Leguminosæ, Malvaceæ, and many other cultivated crops.
Enemies: Animal—Mongoose; birds; lizards; frogs.
Arthropod—Centipede; spiders; *changa* (eats larvæ); fire-ant. No parasites recorded.
Fungus—Metarrhizium.
Control: Shaking from foliage (citrus) onto sheets, then destroying; turning hogs into cane fields at plowing, to consume stubble; poisinging of trap crops with arsenicals; frequent shallow plowing when possible; heavy fertilization of plants.

32. *Metamasius hemipterus* Linn. (family Curculionidæ).
Common Name: Sugar-cane stalk-weevil.
Damage: Larvæ bore and breed in cane stalks.
Distribution: Porto Rico; Virgin Islands; Windward Islands; Demerara.
Food Plants: Sugar cane; dead or injured palm trunks; banana trunks (rarely). Adults sometimes attack fruit.
Enemies: Animal—Same as preceding.
Arthropod—Centipede and spiders. No insect enemies recorded, except the fire-ant.
Fungus—Green Muscardine.
Control: Destruction of infested canes; cutting cane close to ground (as beetle breeds abundantly in stubble); destruction of adults by means of trap piles of decayed fruit or peels.

33. *Xyleborus* sp. (possibly *X. perforans* Woll.) (family Ipidæ).
Common Name: Sugar-cane shot-hole borer.
Damage: Perforates standing stalks; also attacks seed cane in the ground.

DISTRIBUTION: Entire Island.
FOOD PLANTS: Sugar cane; no others recorded with certainty.
ENEMIES: Animal—Birds; bats; lizards.
Arthropod—Spiders; predacious bugs; ants.
Fungus—None recorded.
CONTROL: Destruction of infested canes; trap lights; deep planting and prompt planting of seed.

VII. LEPIDOPTERA.

34. *Prenes nero* Fabr. (family Hesperidæ).
COMMON NAME: Sharp-headed cane leaf-roller.
DAMAGE: Attacks foliage of young cane in larval stage.
DISTRIBUTION: Entire Island.
FOOD PLANTS: Sugar cane and grasses.
ENEMIES: Animal—Birds; lizards; frogs.
Arthropod—Ants; predacious bugs; a Braconid wasp.
Plant—A bacterial disease.
CONTROL: Spraying foliage with arsenicals.

35. *Prenes ares* Feld. (family Hesperidæ).
COMMON NAME: Round-headed cane leaf-roller.
DAMAGE: Larva attacks foliage; less common than preceding.
DISTRIBUTION: Entire Island.
FOOD PLANTS: Sugar cane and grasses.
ENEMIES: Same as those of preceding.
CONTROL: Not required.

36. *Atrytone vitellius* Fabr. (family Hesperidæ).
COMMON NAME: Smaller sugar-cane leaf-roller.
DAMAGE: Eats the margins of leaves, and conceals by tying edges of leaf together.
DISTRIBUTION: Entire Island.
FOOD PLANTS: Sugar cane, Sudan grass and wild grasses.
ENEMIES: These have not been studied.
CONTROL: Same as for species of Prenes.

37. *Laphygma frugiperda* S. & A. (family Noctuidæ).
COMMON NAME: Southern grass-worm.
DAMAGE: Larvæ attack young cane in terminal bud.
DISTRIBUTION: West Indies; United States; Mexico; Central and South America.
FOOD PLANTS: Sugar cane; corn; grass; vegetables; tomato fruit; truck crops.
ENEMIES: Animal—Birds; lizards; frogs; bats.
Arthropod—Ants, predacious bugs; wasps; *Ophion* sp.; *Chelonus* sp.; a Braconid; several Tachinids; *Calosoma alternans*.
Plant—Three fungi, *Botrytis rileyi*, *Empusa sphærosperma*, and *Cordyceps* sp.

CONTROL: Spraying or dusting with arsenicals; frequent cultivation to destroy pupæ.

38. *Cirphis* (*Heliophila latiuscula*) H. S. (family Noctuidæ).

COMMON NAME: Sugar-cane cutworm.
DAMAGE: Larvæ eat the foliage.
DISTRIBUTION: Entire Island; Santo Domingo.
FOOD PLANTS: Sugar cane, sorghums and grasses.
ENEMIES: Animal—Birds; bats; lizards; frogs.
Arthropod—Ants; predacious bugs; wasps; a Braconid and a Chalcidid; several Tachinids.
Plant—Green fungus, *Botrytis rileyi* and *Cordyceps* sp.
CONTROL: Not required.

39. *Mocis* (*Remigia*) *repanda* Fabr. (family Noctuidæ).

COMMON NAME: Grass looper.
DAMAGE: Larvæ attack foliage of young cane.
DISTRIBUTION: West Indies; eastern U. S.; South America.
FOOD PLANTS: Sugar cane and grasses.
ENEMIES: Animal—Same as of preceding.
Arthropod—Spiders, ants, predacious bugs and wasps; an Ichneumonid; a Braconid; a Tachinid.
Fungus—*Botrytis rileyi* and *Cordyceps* sp.
CONTROL: Not required, as attack to cane is uncommon.

40. *Diatræa saccharalis* Fabr. (family Pyralidæ).

COMMON NAME: Sugar-cane moth stalk-borer.
DAMAGE: Larvæ bore the stalk, weaken plant and reduce sucrose.
DISTRIBUTION: West Indies; southern U. S.; Mexico; Central and South America.
FOOD PLANTS: Sugar cane; corn; sorghum; Paspalum; rice.
ENEMIES: Animal—Same as those of the grass-worm.
Arthropod—Spiders; predacious bugs; a Tachinid fly; egg parasite, *Trichogramma minutum* Riley.
Fungus—*Isaria* (*Cordyceps*) *barberi*.
CONTROL: Prompt and regular uprooting and burning of deadhearts; discontinuance of trash burning; destruction of wild Paspalum grass; selection of seed; deep planting of seed; trap lights.

41. *Pyralid* (undetermined) (family Pyralidæ).

COMMON NAME: Sudan grass leaf-tyer.
DAMAGE: Larvæ have been found attacking cane leaves; damage to cane rare.
DISTRIBUTION: Probably entire Island.
FOOD PLANTS: Sugar cane; Sudan grass; other grasses.
ENEMIES: No parasites yet observed.
CONTROL: None required.

42. *Ereunitis* sp. (?) (family Tineidæ).
COMMON NAME: Sugar-cane bud-moth.
DAMAGE: Larvæ bore through buds into stalk; occasionally severe.
DISTRIBUTION: Entire Island.
FOOD PLANTS: Sugar cane; no others recorded.
ENEMIES: No parasites thus far observed.
CONTROL: None yet worked out; seldom required. Time of planting affects the amount of infestation.

VIII. DIPTERA.

43. *Chætopsis* sp. (near *C. ænea* Wied.) (family Ortalidæ).
COMMON NAME: Ear-corn maggot.
DAMAGE: Infests tunnels of Diatræa in the stalk, also leaf sheaths infested with mealybug, inducing progressive decay.
DISTRIBUTION: Entire Island.
FOOD PLANTS: Sugar cane tissue; worm-infested corn ears; decaying coconut fiber; etc.
ENEMIES: A Cynipid parasite observed; spiders; ants.
CONTROL: None usually required.

44. *Agromyza* sp. (undetermined) (family Agromyzidæ).
COMMON NAME: Cane and grass leaf-miner.
DAMAGE: Rarely mines the leaves of young cane; commonly mines grass leaves.
DISTRIBUTION: Probably entire Island.
FOOD PLANTS: Sugar cane, sorghum and grasses.
ENEMIES: Small Chalcidid wasp attacks larva and a Cynipid the pupa.
CONTROL: None required.

IX. HOMOPTERA.

45. *Cicadella* (*Tettigonia*) *sirena* Stal. (family Cicadellidæ).
COMMON NAME: Red-striped leafhopper.
DAMAGE: Adult and nymph occasionally attack cane; reared from cane.
DISTRIBUTION: Entire Island.
FOOD PLANTS: Sugar cane; citrus; coffee; sesame; garden plants.
ENEMIES: Animal—Birds; lizards; tree frogs.
Insect—*Conocephalus* (*Xiphidion*) sp.; predacious bugs. No parasites yet recorded.
Fungus—None yet recorded.
CONTROL: Not necessary.

46. *Kolla* (*Tettigonia*) *similis* Walk. (subfamily Cicadellinæ).
COMMON NAME: Green sugar-cane leafhopper.
DAMAGE: Sometimes abundant on young cane, but not directly injurious. Might transmit disease.
DISTRIBUTION: Greater Antilles; southeastern U. S.

FOOD PLANTS: Sugar cane; Para grass; some other grasses.
ENEMIES: Animal—Birds, lizards and tree frogs.
Insect—*Xiphidion* (?); *Zelus rubidus;* a Hymenopterous egg parasite; Attid spiders.
Fungus—None recorded with certainty.
CONTROL: Sweeping grass and young cane with tarred frames; cutting grass near cane fields; crop rotation; introduction of parasites.

47. *Kolla* (?) sp. (not determined) subfamily Cicadellinæ).
COMMON NAME: Gray sugar-cane leafhopper.
DAMAGE: Quite common on young cane; no direct injury.
DISTRIBUTION: South coast and north-west coast.
FOOD PLANTS: Sugar cane and grasses.
ENEMIES: The same as those of preceding species.
CONTROL: None required.

48. *Jassid* (not yet determined) (subfamily Jassinæ).
COMMON NAME: Cane false-mottling leafhopper.
DAMAGE: Attacks leaves of young cane near tips, causing white streaks that resemble mottling disease.
DISTRIBUTION: North coast; possibly entire Island.
FOOD PLANTS: Sugar cane and grasses.
ENEMIES: No parasites yet observed.
CONTROL: Scarcely required.

49. *Balclutha* (*Gnathodus*) sp. (subfamily Jassinæ).
COMMON NAME: Cane seed-head leafhopper.
DAMAGE: Very abundant, in all stages, in seed tassels. Doubtless injures fertility of seed.
DISTRIBUTION: Entire Island.
FOOD PLANTS: Sugar cane and false Para grass, *Eriochloa subglabra;* occasionally other grasses.
ENEMIES: Animal—Same as those of Kolla.
Insect—A Dryinid, *Chalcogonatopus* sp., infests sometimes over 50 per cent of adults and nymphs; a Mymarid parasitizes large per cent of eggs; a Syrphid fly.
Plant—A fungus, undetermined, parasitizes all adults after attack by Dryinid.
CONTROL: Keep cut, in vicinity of cane fields, the "malojillo" (Eriochloa) upon whose seeds it feeds through the year.

50. *Bothriocera* sp. (probably new) (family Fulgoridæ).
COMMON NAME: Gray fulgorid-fly.
DAMAGE: Taken rarely feeding on cane; does no damage.
DISTRIBUTION: Entire Island; Vieques.
FOOD PLANTS: *Citrus* spp.; *Palicourea* spp.; *Anona* spp.; *Piper aduncum;* sugar cane (rarely); etc.
ENEMIES: No insect parasites recorded. A fungus, *Isaria saussurei* Cooke (det. J. A. Stevenson), attacks insect heavily on Palicourea and Piper.
CONTROL: None required.

51. *Oliaris* sp. (subfamily Cixiinæ).
   Common Name: Cottontail plant-hopper.
   Damage: Quite common on young cane, but no injury thus far observed.
   Distribution: Entire Island.
   Food Plants: Feeds upon a great variety of plants and trees. Younger stages not known.
   Enemies: No insect or fungus parasites observed.
   Control: Not necessary.

52. *Ormenis* sp. (subfamily Flatinæ).
   Common Name: Moth-hopper.
   Damage: Recorded by Van Dine[1] as "found breeding on cane leaves in one instance." Not observed on cane by the writer. Injury to cane inconsequent.
   Distribution: Not recorded.
   Food Plants: Cannot be given. as species was not recorded.
   Enemies: Insect—A Hymenopterous parasite infests a large proportion of eggs of the two commoner species; a Syrphid larva feeds on eggs: a Dryinid rarely attacks nymphs.
   Fungus—*Metarrhizium anisopliæ*, form *minor* (det. J A. Stevenson). has been found by writer infesting many adults of a common species on coffee.
   Control: Not required on sugar cane.

53. Derbid (not yet determined) (subfamily Derbinæ).
   Common Name: Veil-wing moth-hopper.
   Damage: Sometimes very abundant at bases of mature cane. Injury not observed. Younger stages unknown.
   Distribution: North coast.
   Food Plants: Sugar cane; a wild fern.
   Enemies: No insect or fungus enemies yet observed.
   Control: None required.

54. *Stenocranus* (*Delphax*) *saccharivorus* Westw. (subfam. Delphacinæ).
   Common Name: West Indian cane-fly.
   Damage: All stages on foliage; feeding punctures give entrance to disease: honeydew causes black mold on foliage. Becomes extremely abundant on plants in confinement, but is scarce under field conditions.
   Distribution: Porto Rico: Santo Domingo: Jamaica: southern U. S.; Barbados.
   Food Plants: Sugar cane; can breed on grasses, but rarely does.
   Enemies: Animal—Birds: tree frogs: lizards, especially *Anolis pulchellus*.
   Arthropod—Spiders: *Zelus rubidus; Franklinothrips vespiformis;* a Mymarid egg parasite; a

[1] In Jour. Econ. Ent., Vol. 6, No. 2, Apr. 1913, page 257.

Dryinid wasp; a Stylopid, *Stenocranophilus quadratus* Pierce, which is more beneficial than all other parasites combined.
Plant—A green fungus, not determined, rarely attacks adults.
CONTROL: Not required, due to lizards, parasites, and beating rains.

55. *Perkinsiella* sp. (undetermined) (subfamily Delphacinæ).
COMMON NAME: White-lined plant-hopper.
DAMAGE: Sometimes common on young cane, but does no noticeable damage; breeds on rice.
DISTRIBUTION: Entire Island.
FOOD PLANTS: Sugar cane, rice and grasses.
ENEMIES: No parasites yet recorded; a predacious Mirid bug.
CONTROL: None required.

56. *Aphis setariæ* Thos. (family Aphididæ).
COMMON NAME: The brown cane aphis.
DAMAGE: Infests stalk at the base of leaf sheaths; occurs uncommonly, on isolated canes.
DISTRIBUTION: Porto Rico; southern U. S.: probably other Greater Antilles.
FOOD PLANTS: Sugar cane and grasses.
ENEMIES: Arthropod—Small spiders; Syrphid flies; several Coccinellid beetles; an internal parasite.
Fungus—Not recorded.
CONTROL: Too rare to require control. Thrives only when protected by the fire-ant, *Solenopsis geminata,* which builds earth shelters over colonies.

57. *Sipha flava* Forbes (family Aphididæ).
COMMON NAME: Yellow sugar-cane aphis.
DAMAGE: Infests undersides of leaves, especially near tips of lower leaves; often becomes epidemic over considerable areas.
DISTRIBUTION: Porto Rico; southern U. S.; probably other Greater Antilles.
FOOD PLANTS: Sugar cane and grasses.
ENEMIES: Animal—A lizard, *Anolis pulchellus.*
Arthropod—Small spiders; Coccinellids; Syrphid flies.
Fungus—*Agrostalagmus albus* reported by J. R. Johnston; never observed by writer.
CONTROL: No artificial control practicable, except in seedling plots, as parasites effect control promptly.

58. *Aleyrodes* sp. (apparently new) (family Aleyrodidæ).
COMMON NAME: Sugar-cane white-fly.
DAMAGE: Insignificant; attacks foliage, but appears to be rare.

DISTRIBUTION: Recorded only from Río Piedras by the writer.
FOOD PLANTS: None other than cane recorded.
ENEMIES: Parasitized by minute Hymenopteron.
CONTROL: None called for.

59. *Pseudococcus calceolariæ* Mask. (family Coccidæ).
COMMON NAME: Pink sugar-cane mealybug.
DAMAGE: Attacks roots, and the stalks at the nodes, stunting growth and inducing rot beneath leaf sheaths.
DISTRIBUTION: West Indies; Demerara; southern U. S.; California; Hawaii; Fiji; New Zealand.
FOOD PLANTS: Sugar cane; probably grasses; several other plants in other localities.
ENEMIES: Animal—Blackbirds; honey-creepers; rats and mice; lizards.
Arthropod—Earwigs; a predacious bug, near Triphleps; a Eulophid parasite; a Cecidomyid, *Karschomyia cocci* Felt; *Franklinothrips vespiformis;* a Coccinellid, *Cryptolæmus montrouzieri* (rarely).
Fungus—*Aspergillus flavus* and *Isaria* sp.
CONTROL: Treatment of cane seed; seed selection; use of self-stripping varieties; clean cultivation prior to planting; elimination of the fire-ant.

60. *Pseudococcus sacchari* Ckll. (family Coccidæ).
COMMON NAME: Gray sugar-cane mealybug.
DAMAGE: Practically the same as that of *P. calceolariæ,* but less common.
DISTRIBUTION: Porto Rico; Barbados; Trinidad; Mexico; California; Hawaii; Mauritius.
FOOD PLANTS: Sugar cane and grasses.
ENEMIES: The same as of preceding species.
CONTROL: Same as for pink mealybug.

61. *Pseudococcus* sp. (?) (apparently undescribed) (family Coccidæ).
COMMON NAME: Sugar-cane leaf mealybug.
DAMAGE: Attacks the leaves and leaf sheaths, especially of young cane. Has caused death of cane in confinement. Rarely observed in fields.
DISTRIBUTION: Not yet determined. Collected at Río Piedras by the writer.
FOOD PLANTS: Sugar cane and grasses.
ENEMIES: A Eulophid parasite and the Cecidomyid keep it in control.
CONTROL: None required.

62. *Pulvinaria iceryi* Guer. (det. by H. Morrison) (fam. Coccidæ).
COMMON NAME: Sugar-cane leaf scale.
DAMAGE: Attacks the leaves only; multiplies rapidly. Has killed young plants in confinement. Rare in the fields.
DISTRIBUTION: Entire Island; Mauritius; Reunion Island.

FOOD PLANTS: Sugar cane; grasses (rarely).
ENEMIES: Two species of Hymenopterous parasites; a Cecidomyid larva.
CONTROL: Held in check by parasites.

63. *Aclerda tokionis* Ckll. (det. by E. R. Sasscer) (fam. Coccidæ).
COMMON NAME: Larger sugar-cane stalk scale.
DAMAGE: Attacks the stalk on or near leaf sheaths. Rare.
DISTRIBUTION: Porto Rico; California; Japan. Recorded from Río Piedras and Guayama by Wolcott; not observed by writer.
FOOD PLANTS: Sugar cane (Porto Rico); bamboo (California and Japan).
ENEMIES: None recorded.
CONTROL: Not required.

64. *Targionia* (*Aspidiotus*) *succhari* Ckll. (det. E. R. Sasseer) (fam. Coccidæ).
COMMON NAME: Smaller sugar-cane stalk scale.
DAMAGE: Occurs frequently on stalk at nodes, but seldom abundantly.
DISTRIBUTION: Porto Rico; Jamaica; Barbados; Antigua; Java.
FOOD PLANTS: Sugar cane and grasses.
ENEMIES: A Hymenopterous parasite observed.
CONTROL: None required.

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65. *Degeeria* sp. (?) (family Entomobryidæ).
COMMON NAME: Green springtail.
DAMAGE: Always present on undersides of foilage. Exact nature of damage not yet determined. Of doubtful economic importance.
DISTRIBUTION: Entire Island.
FOOD PLANTS: Sugar cane; banana; cotton; foliage of many plants and trees.
ENEMIES: No predacious insect enemies or parasites thus far observed.
CONTROL: Not considered to be necessary.

PREVIOUS PUBLICATIONS OF THE YEAR (1919-1920).

1. Annual Report of the Insular Experiment Station of the Department of Agriculture and Labor (1918-1919) of Porto Rico.
2. Journal of the Department of Agriculture. Vol. III, No. 3, The Mottling or Yellow-Stripe Disease of Sugar Cane, by John A. Stevenson.
3. Bulletin No. 19. The Resistence of Cane Varieties to Yellow-Stripe or the Mosaic Disease, by F. S. Earle.
4. Boletín No. 20. Insecticidas y Fungicidas, por I. A. Colón.
5. Boletín No. 21. Abonos (1918-1919), por F. A. López Domínguez.
6. Circular No. 17. Recomendaciones sobre el Cultivo de la Caña de Azúcar en Puerto Rico, por F. S. Earle.
7. Circular No. 18. El Exterminio de la Garrapata, por J. Bagué.
8. Bulletin No. 22. Eradication as a Means of Control in Sugar-Cane Mosaic or Yellow Stripe. The Year's Experience with this Method, by F. S. Earle.
9. Circular No. 19. La Mezcla de Abonos por el Agricultor, por F. A. López Domínguez.
14. Boletín No. 22. (La Edición Española.) La Extirpación del Mosaico de la Caña como Medio de Represión, por F. E. Earle.

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